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SHOULD GLEN CANYON DAM BE REMOVED?

By
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A thesis submitted to the
University of Colorado at Boulder
in partial fulfillment
of the requirements to receive
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Abstract:

Through research on the contemporary debates and studies pertaining to Glen Canyon Dam, this paper objectively addressed the proposal to drain Lake Powell. This thesis reaches a conclusion that advocates decommissioning the Glen Canyon Dam. This paper approaches the concise, yet multi-dimensional question of whether or not to drain Lake Powell by most basically weighing the benefits and costs of both keeping and removing Lake Powell through an analysis of the effects on various parties. The areas of interest in which existing empirical data is available in order to sculpt a comprehensive and supported opinion that will simply answer the central question are: logistical feasibility of such a proposition, adverse effects on power generation, sedimentation, water supply and distribution, recreation, and ecology (especially fish). On the subject of hydroelectric power produced by Glen Canyon Dam it is prudent to not decommission the dam, for a clean and cheap power source with peaking capabilities would be eliminated. Because sediment will eventually fill in the lake and is always increasing the time to a restored Glen Canyon, I advocate draining Lake Powell. The use of Lake Powell as a storage facility will not be realized for some time and increased evaporation from the lake also supports the movement to decommission the dam. The fact that recreation will continue in the Glen and Grand Canyons in the absence of Lake Powell aligns with the motion to drain Lake Powell, and the ecological harm that is a result of the Glen Canyon Dam (both within Lake Powell and in the Grand Canyon) is yet another reason to support decommissioning the Glen Canyon Dam. By analyzing the various aspects of the above categories in respect to a proposal to drain the contents of Lake Powell, This paper responds in favor of decommissioning Glen Canyon Dam.

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Preface

My personal experience with the West, Lake Powell, and even the Colorado watershed as a whole, stretches back to before memory. Born to an outdoor family of particular water-lovers, I have rarely let a year pass without spending a week on Lake Powell. I have experienced it in all of the ways popular to tourists: weeks on houseboats far away in secluded side canyons, camping trips from a speed-boat, day excursions from the base of a motor home, rented double-wide trailer, or hotel room, guided tours of Glen Canyon Dam, and just scenic drives to admire the lake from afar. In addition, I have played in the lake on houseboats, water ski boats, wakeboard boats, jets skis, tubes, surfboards, and more. In short, I have experienced intimately and extensively what Lake Powell has to offer and therefore, a major part of what the Glen Canyon Dam has to offer, although, as will soon be evident, impacts of the dam stretch far beyond the shores of Lake Powell.

From the above brief history of my Lake Powell experiences, it would seem that the lake and the dam have provided me with nothing but happiness. Another form of prominent outings within my upbringing, however, has turned out to instill beliefs in me that directly conflict with many of the principles of Lake Powell. Again, since my fourth birthday, it has been a yearly necessity to go whitewater rafting. Just like my many and varied experiences on Lake Powell, I have been a passenger on commercial and private rafts, as well as rowed both types, kayaked, inflatable kayaked, guided, paddle boated and

paddle guided, on over 13 rivers spanning two continents. So much has river rafting been a part of my life that I have spent recent summers as a guide, showing the beauty of Dinosaur National Monument to many ecstatic and awe-inspired clients.

I reveal all this, not to revel in my fortunate outdoor experiences and accomplishments, but to set up the dichotomy that has ultimately led to this paper. Any of the over two million annual (McKinnon, 2007) wakeboarding, waterskiing, boating, fishing, or traveling enthusiasts who visit Glen Canyon National Recreation Area will light up at the mention of Lake Powell, for it is a tourist's Mecca to enjoy such above-mentioned recreation in a very unique setting. However, at the same time, any rafting or river lover will surely cringe at the mention of Lake Powell that drowned the pristine Glen Canyon, or hiss at any allusion to a dam, especially enormous dams that erase and alter rivers forever. Having witnessed this situation from many different vantage points, in the past years, I have frequently asked myself the most central question in the most unbiased manner: should Lake Powell be drained?

Introduction

With over 1,900 miles of shoreline, Lake Powell is an unusual sight in a landlocked arid region of the Southwestern United States. This landmark that some love, and others hate, is the result of the Glen Canyon Dam, a 710 foot tall concrete barrier that when full can hold back 26, 215,000 acre-feet of Colorado River water (Martin, 1989). Millions of people find nothing but beauty and enjoyment in the deep blue water and scoured sandstone cliffs that make up the National Recreation Area stretching 186 miles behind the dam. Others, who may have no direct experience with the lake itself, also find the resulting hydroelectric power from the turbines within the dam to be an essential source of clean energy in the West. However, as alluded to, still others despise the giant barrier and the consequences of the lake it creates, both ecological and interest-based. In the contemporary period in which environmental movements have a say in every issue, and even have the power to back up their opinions in the arena of popular politics, a motion to undo past actions is gaining momentum. A discussion to essentially turn back time by draining Lake Powell is never far away from any conversation about the lake or the dam.

When Glen Canyon Dam was under way in 1957, no thought was given to the health of an ecosystem or of the environment. No legislation existed that mandated environmental considerations be raised before the government embarked on any project, and it would be another decade before such laws were introduced in the United States. Instead, the Glen Canyon Dam was constructed on the heels of a large dam building frenzy by an enormous engineering machine, The Bureau of Reclamation. When it was built, the Glen Canyon Dam served all of its intended purposes and still does, to some

extent, today. Authorized to store water for future use by the Lower Basin states and provide hydroelectric power to a booming West, the Glen Canyon Dam's other benefits included recreation and flood control (Rogers, 2006). Now, after more than 40 years in operation, the Glen Canyon Dam still stores precious water for downstream consumption, and continues to produce emission-free hydropower, yet sedimentation and evaporation have cut into the amount of water that can be stored in Lake Powell, and environmental concerns have led to reduced hydropower output. The recreation opportunities above and below Glen Canyon Dam continue to thrive as well.

Now that the environment has a voice and a following in society, however, curiosity leads us to question if Glen Canyon Dam should have been constructed in the first place. In many such questions, the answer is trivial, as the realistic possibilities of decommissioning most of these impressive construction feats are slim. In the case of the Glen Canyon Dam, however, the possibility of removal is grounded and feasible, while constantly gaining support. It is for this reason, the plausible nature of decommissioning Glen Canyon Dam, that the ensuing debate must be carefully considered, for we are presented with a rare instance in which past mistakes or ill-informed decisions of such magnitude can be reassessed and possibly reversed. By investigating power generation, sedimentation, water supply and distribution, recreation, and ecological effects of the Glen Canyon Dam and the projected changes in the absence of Lake Powell, I will form a conclusion of the future of the Glen Canyon Dam. Before this can be accomplished, though, background on the issues surrounding the dam, and on the dam itself, is necessary to set the stage.

Background

Large Dam Enthusiasm

Within the core values of the famed notion of Manifest Destiny that shaped America's frontier expansion is the recognized need to break away from the feudal past of Europe (Smith, 44). In no other way is this idea more evident than the enthusiastic large-dam-building period in America that essentially lasted until the completion of the Glen Canyon Dam in 1963. It was in the vast expanses of the "untamed" West, however that some of the most notable dams were erected. Prior to 1869, the American West was "a land that could not be plowed, grazed or even crossed" (Ward, 2004), a symbol of nature's few remaining and undomesticated wilderness areas that changed beginning with the famous expeditions of John Wesley Powell. In 1869, Powell, a dogged Civil War veteran, finally navigated the last blank pieces on Western maps, via the Green River to the Colorado River and then down through Glen Canyon, and the Grand Canyon to end at the confluence of the Colorado and Virgin River in Southwestern Utah over three months later.

This monumental expedition, as well as others that followed, convinced Powell of the fact that too little water existed in the desert West to transform the arid frontier into an eastern model of tamed farmland. The water that was present, Powell contended, existed in such remote locations and sporadic seasons that "water and land had to be used in common, with the federal government taking the lead in building dams where they would do the most good" (Ward, 2004). Although Powell's rationale was based on meticulously observed scientific data and humbling personal experience that revealed to him the improbability, if not sheer scale, of an effort to cultivate the West in a traditional

Eastern or European manner, the relentless thirst of a new nation built on capitalism and insatiable expansion knew only one solution: the big business of big dams. Powell's vision (one that is not explicitly agreed upon today) advocated a radical shift in basic political and farming practices in order for progress and settlement to be achieved in the unique situation of the West. Yet, his advice and foresight have been used to fuel sharp opposition. Dam builders institutionalize the waters of the West in Powell's name, citing his call for federal aid in Western water infrastructure, while dam opponents imagine Powell turning in his grave upon seeing the immense barriers and projects that irreversibly alter the ecology of the rivers he loved and unsustainably support a civilization in a hostile climate (Ward, 2004).

In an era of engorged human ingenuity and plentiful public works projects, however, water in a thirsty land became a lucrative market and the powerful constituency behind those willing to capture this water was uncontested (Ward, 2004). As a result, the era of large dam building began. In 1888 the 140-foot tall Lower Crystal Springs Dam in central California was completed and still stands to this day (U.S. Geological Survey, 2003). Structures such as the Elwha Dam and the Glines Canyon Dam plugged Washington's Elwha River in 1913 and 1927 respectively (NPS.gov). Other dams over 100-feet tall also began to dot California and the Pacific Northwest in the early twentieth century.

By 1902 pressure on the Federal Government was mounting to shoulder storage and irrigation projects. The growing population that was moving west had realized that inadequate precipitation beyond of the 100th meridian required the use of irrigation for agriculture. Therefore, the Reclamation Act of 1902 sought to "reclaim" arid lands—for

the purpose of farming—and do so on a large scale with resources that were only available at the federal level. In the five years after 1902, the Reclamation Act had spurred 30 projects western states, with many more to come (USBR.gov).

The CRB was developed first with the monumental success of Hoover Dam in 1936 and many dams later, capped off with the completion of Glen Canyon Dam and the formation of Lake Powell, on the same river in 1963. It is ironic that America's obsession with building Western dams began and ended on the Colorado River, as if the Glen Canyon and Hoover Dams are “monumental parentheses enclosing America's era of big-dam building” (Ward, 2004), as author Chip Ward astutely puts it. Yet, this way of highlighting such a period in history also points to the significance of a river like the Colorado in a region such as the arid West.

The above summary is a glimpse at how the West's water came to be developed by massive infrastructure, interstate compacts and, for the purpose of this debate, large dams. Numerous instances of controversy have characterized the water development in a land opened to the world by John Wesley Powell. For decades, engineers have exacted their wills upon temperamental Western rivers in the name of Powell, but recently, opposition to such federal creations has also adopted the legacy of Powell to support their concerns. However, from this point forward I will narrow my focus to one large dam in particular, the Glen Canyon Dam, in an attempt to separate the convoluted facts in the argument to maintain or drain Lake Powell.

Glen Canyon Dam

Colorado River Compact

In order to understand the desire behind removing the Glen Canyon Dam, knowledge of how the dam came about is necessary. The Colorado River, running over 1,400 miles through the arid American West, is possibly the most regulated river in the world. Ever since John Wesley Powell first explored the river, its precious water in the midst of a desert landscape began to be appropriated all around the developing West. At first, riverside settlements in the upper reaches of the watershed began extracting water for municipal and agricultural uses; however, before long, swelling urban centers as well as prosperous farming regions began to haul more and more Colorado River water farther away from its desert canyons and streambeds. In 1922 the Colorado River Compact marked the beginning of numerous pieces of management literature that have sought to equitably share the river basin's valuable and contested resource. The 1922 Colorado River Compact allocated every last drop of water in the river to the seven basin states: Colorado, New Mexico, Utah, Wyoming, Arizona, California, and Nevada, as well as some to the country of Mexico (Water in the West, 1998). Since then, a host of legal stipulations have grown to dictate the management and operation of the Colorado River, totaling twelve major, and many minor, federal and state laws, treaties, court decisions, and compacts that are commonly referred to as the "Law of the River."

The most fundamental agreement that governs the Colorado River Basin (CRB), however, is the Colorado River Compact of 1922. In this document, the Colorado River system is defined as the Colorado River itself and its tributaries. The Colorado River Basin, however, encompasses all of the area drained by the Colorado River System as

well as other lands on which waters of the Colorado River System are beneficially applied (USBR Report, 2005). The Colorado River Compact of 1922 also divided the Colorado River Basin into the Upper Basin and the Lower Basin at Lees Ferry, located on the main branch of the Colorado River in Arizona (River Compacts, 2003). Ecosystems and watersheds are typically divided to conform to political boundaries and functions. The CRB is no exception and was artificially divided in two. The Upper Basin states are Colorado, New Mexico, Utah, and Wyoming, while California, Nevada, and Arizona comprise the Lower Basin states. The impetus for proposing the 1922 compact arose as the Upper Basin states realized the rapid growth occurring in such Lower Basin states as California and became concerned that any storage on the river would be put to immediate use by booming downstream regions. Lower Basin states would therefore be able to claim “first come, first serve” appropriative water rights (Burness, 1980), effectively securing Upper Basin water in times of drought. It is clear why the more slowly developing Upper Basin states would seek provisions to ensure water for future growth. Therefore, the basis of the 1922 Colorado River Compact lies in the difficulty encountered as both the Upper and Lower Basin states attempted to more equitably share the limited water that they had.

Prior Appropriation

Furthermore, the antiquated and unique doctrine of prior appropriation plays into the allocation of the Colorado River. Contrary to doctrines of riparian water rights employed in the rest of the U.S., the laws governing water rights in the West were tailored in an attempt to address the hydrologic and social differences at work in the far more arid CRB and elsewhere. The Common Law riparian water rights observed in the

more humid eastern U.S., allows for “reasonable” withdrawals by riparian residents, or those living near the water and using the water, and assumes a high rate of return flows back into the watershed that can then be reused downstream (Burness, 1980). Water use in the dry CRB, however, is dominated by irrigated agriculture, a water intensive act with very low return flows back into the Colorado River. Therefore, Western water users long ago established the unique doctrine of appropriative rights to determine the destination of Colorado River water. Appropriative water rights are obtained by physically diverting water and putting it to beneficial consumptive use. Much of the controversy surrounding the appropriative water rights doctrine comes from the priorities that are determined on a “first-come, first-served” basis (Burness, 1980). Whoever began to extract and use the water of the Colorado River first, in the appropriative rights doctrine, is entitled to use the water for the longest in times of reduced flow.

Colorado River Storage Project

With a sense of the importance of the Colorado River to stakeholders in the West, and some knowledge about the urgency of guaranteeing water for future use, the Colorado River Storage Project can be introduced. The Bureau of Reclamation was charged with appropriating the now divided Colorado River water (Ward, 2004), and first did so in an impressive manner. Hoover Dam, constructed in Boulder Canyon where the Colorado exited the Grand Canyon and meandered into Nevada, was finished in 1936 and was revealed as an engineering marvel. In fact, the Glen Canyon Dam site was considered while looking for a place to build Hoover Dam, but was eventually ruled out due to being too far away from roads and potential water and electricity users (Ward, 2004). Instead, Boulder Dam, later renamed Hoover Dam, was a massive success in the

views of both the public and the Bureau of Reclamation, so much so, that the era of large dam building began. After Hoover Dam, the Upper Basin voiced its desire for water projects. As a result, the Bureau of Reclamation designed the Colorado River Storage Project in the early 1950s in which “four dams and reservoirs would be raised—one at Bridge Canyon on the Colorado just downriver from Grand Canyon National Monument; one above Lees Ferry in Glen Canyon; one on the Green River at Flaming Gorge, by the Utah-Wyoming border; and another on the Green River, in Dinosaur National Monument’s Echo Park” (Ward, 2004).

The prospect of the Grand Canyon and much of Dinosaur National Monument disappearing under reservoirs was enough to spur David Brower and the fledgling Sierra Club into bitter opposition. In a battle that ultimately propelled the Sierra Club into a powerful and prominent organization that in turn spearheaded the environmental movement of the 1960s and 1970s, Brower stood up to the Bureau of Reclamation. The compromise that was eventually reached was a Colorado River Storage Project with dams in Flaming Gorge and Glen Canyon; the Grand Canyon and Dinosaur National Monument were preserved (Ward, 2004). Before the National Environmental Protection Act of 1970 (NEPA) existed to require an assessment of the environmental impacts of building dams, or Brower even had a chance to visit the marvelous Glen Canyon that he sacrificed in order to save two other beautiful sections of river, the Glen Canyon Dam was begun in 1957.

In order for the massive undertaking of building a 710-foot tall dam in an utterly remote location to become reality, a new community had to spring up from scratch to support those involved in the project. According to the U.S. Geologic Survey, in the

1950s, the Glen Canyon Dam site existed quite literally in “the most isolated area [with] the fewest people, fewest roads and fewest settlements, in the nation” (Alaska was still just a territory) (Martin, 1989). Nonetheless, people and supplies poured into the desert from around the country, and in some cases, the world, many having secured lucrative and unique contracts from the U.S. government. Among the vast array of contracts that the Bureau of Reclamation entered into while building Glen Canyon Dam, ranging from a contract to supply 100,000 gallons of lubricating oil to the 2.4 million dollar contract to Mountain States Construction for the job of carving out the diversion tunnels, was the prime contract for the construction of the dam and power plant themselves. The lowest bidding company that walked away with this task, was construction giant Merritt-Chapman & Scott, who believed that such a structure could be built for a mere \$107,955,522, a number \$28,044,478 less than the Bureau had estimated, and more than \$10 million shy of the bids from the other two construction conglomerates in the hunt (Martin, 1989). Whether or not a profit was in store for Merritt-Chapman & Scott, in early June of 1957 Glen Canyon Dam was under way, and with it was the construction and growth of Page, Arizona, the future town that would grow from a temporary construction camp located on a bargained-for Navajo mesa perched on the east bank of the dam site (Martin, 1989). Many tons of dynamite and even more concrete later, in 1963, Glen Canyon Dam was closed and Lake Powell reservoir began swallowing Glen Canyon, a process that took seventeen years to complete (“River and Dam Management”, 1987).

The ten-million ton concrete plug in Glen Canyon was the fourth highest gravity-arch dam in the world. Such a behemoth that was built to last for a thousand years

ultimately demanded five million barrels of cement, ten million cubic yards of aggregate, three million board-feet of lumber, 130,000 tons of steel, 20,000 tons of aluminum, 5,000 tons of copper, and a workforce that topped out at 2,500 men, all meticulously put together in a little less than seven years (Martin, 1989). The Glen Canyon Dam houses 8 massive turbines that can produce up to 1,296,000 kilowatts of hydropower. This electricity is sold to 1.7 million people in Arizona, Colorado, Utah, Wyoming, New Mexico, and Nevada (Report to Congress: Operations of Glen Canyon Dam, 2001). The actual concrete structure of the Glen Canyon Dam however, would be the cause of little upheaval if it weren't for the 186-mile long reservoir that backs up behind it, and it is this man-made sea that ultimately outrages conservationists.

Lake Powell

Lake Powell is the direct result of the Glen Canyon Dam and therefore the origins of the two creations, the dam and the lake, are identical. It is Lake Powell, however, that is either a menace or a gem to those concerned. The reservoir lies within Glen Canyon National Recreation Area, a 1.2 million acre stretch of high desert landscape in southern Utah and Northern Arizona (Friends of Lake Powell). The term “national recreation area” that was already given to the region surrounding Lake Mead, can be interpreted as “a designation applicable to public lands that were neither wild nor undisturbed but nonetheless offered particular opportunities for outdoor enjoyment” (Martin, 1989). Although the waters of Lake Powell cover only 13 percent of Glen Canyon National Recreational Area, the lake is the major draw to the area's over three million visitors each year. In fact, the average tourist stays in Glen Canyon National Recreation Area for 4.5

days, the longest average of any federal park (Friends of Lake Powell). Something is enticing such crowds to the man-made, watery playground of Lake Powell, and upon visiting the area the lure is clear. Some 95 majestic side canyons await exploration by anyone with a watercraft or a desire to hike, and the “stained, striped, orange cliffs of spalling Navajo sandstone” (Martin, 1989) contain a deep blue oasis in the midst of the nation’s last frontier. A man-made object as beautiful as Lake Powell would seem a success to most. This is especially so when one realizes that due to the houseboats or hotels of tourist-thirsty Page, AZ, countless more people who never would have made the trip to the isolated natural beauty by mere way of river or extensive desert trek now enjoy the area. In short, the existence of Lake Powell allows many more people to experience the beauty of the region, even if the way in which this splendor is enjoyed includes jet skis and twelve-packs.

Those in opposition to the lake, on the other hand, do not see the appeal of a unique region that is now accessible via an engineering marvel. Yes, if the lake were a natural wonder in the middle of the desert Southwest, then these ardent environmentalists who condemn Lake Powell would be able to recognize it’s allure. But instead, the population that detests Lake Powell can see right to the bottom of the deep Glen Canyon, through the hundreds of feet of Rocky Mountain water, and recognize that the river that once flowed there, and the side canyons that are now drowned, encapsulated magnificence far surpassing that of Lake Powell. This sentiment, along with the adverse impacts of the lake, and in ways the dam, provides the basis of the movement to drain Lake Powell and thus the basis of the analysis in this paper.

Sentiment Towards Dams

In the midst of the struggle to erase the Echo Park Dam from the Colorado River Storage Project it seemed to those few who had ventured into the majestic Glen Canyon that an overlooked gem in the American West was being hastily sacrificed in order to save the Green and the Yampa rivers above Echo Park. Prior to the attention that the dam brought, Kenneth Sleight was certainly the most recurrent visitor within the sandstone confines of Glen Canyon and it was his fondness of this unseen canyon that prompted him and a few of his fellow outdoor activists at the University of Utah to form the Friends of Glen Canyon (Martin, 1989). Sleight's fledgling group attempted to focus some attention on Glen Canyon, but in reality, represented a concern for a place that was voiced to soon to reach a substantial audience with a vested interest in the canyon. Sleight firmly contended that, "it was absolute insanity to drown nearly 200 miles of canyon just to generate a little electricity, just to make sure you could send water on downstream, a direction in which it so far had exhibited no trouble in traveling" (Martin, 1989). Yet it was not until the fate of the canyon was sealed and construction on the dam had begun that more people began to experience Glen Canyon. Certainly Sleight, like many others, never wanted to see Glen Canyon flooded in the first place, however, his creation of Friends of Glen Canyon as an attempt to draw attention to the place that the conservationists seemed strangely comfortable with losing can be directly linked to the first dreams and the later calls to remove the dam.

Enticed by what was soon to be lost, and perhaps lured by the faint propaganda of Sleight, novelists Edward Abby and friend Ralph Newcomb floated Glen Canyon in June 1959 (Martin, 1989). Deep in Glen Canyon, and years before he became the central voice

that connected dedicated droves of action-minded environmentalists, Abbey's negative interpretation of large dams and their consequences was being sculpted and reinforced. Eight years later, Edward Abbey returned to Glen Canyon as a National Park Service Ranger, an experience that only reinforced his now passionate views; views that surfaced in his novel *Desert Solitaire* soon thereafter. *Desert Solitaire* oozed with Abbey's contempt for canyon-inundating structures such as the Glen Canyon Dam, and reads with an air of certainty that Lake Powell is only temporary. Abbey, the inspiration for a new environmental movement, wrote that it is only a matter of time before, "some unknown hero with a rucksack full of dynamite strapped to his back will descend into the bowels of the dam...[and] ignite the loveliest explosion ever seen by man, reducing the great dam to a heap of rubble in the path of the river" (Abbey, 1968). This half-serious notion sparked hope into the readers of *Desert Solitaire*, bringing into the realm of possibility that a ten million ton dam could actually be removed and a few dozen years of floods and natural processes could return the wondrous Glen Canyon of before.

As Abbey fantasized about Glen Canyon Dam in eventual ruin, (the resulting concrete and rubble-strewn rapid being called Reclamation Commissioner Floyd Dominy Falls), he made no further mention of such a terrorist act in *Desert Solitaire* (Martin, 1989). Nonetheless, Abbey's growing numbers of followers were bitten by the infectious notion that Glen Canyon Dam had to go. Again, in 1971, Abbey's written words condemned the same plug in the Colorado River, as he insisted in the Sierra Club book *Slickrock* that, "Glen Canyon Dam already was sorely obsolete, such a technological dinosaur that surely the thing to do was to open the diversion tunnels and drain the reservoir" (Martin, 1989). This less destructive and fanatical approach to realizing a

future pristine and natural Glen Canyon is the basis of the modern call to drain Lake Powell. Four years later, Abbey's *The Monkey Wrench Gang* was released, and by this time in 1975 the ball had begun to roll toward a public opinion that is in opposition to massive dams, and the Glen Canyon Dam was soon to become the centerpiece for such a discussion.

Draining Lake Powell

The initial resistance, mustered by Brower and the emerging environmental movement, against the Glen Canyon Dam was based mainly in the loss of the serene Glen Canyon. Nobody, however, bothered to imagine the far-reaching consequences that operating such a dam might have, especially on downstream habitat. This ignored foresight is clear in the explicit language of the Act that created the Glen Canyon Dam. The Colorado River Storage Project Act declared that the dam “was to be managed for regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize . . . the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Basin Compact, respectively, providing for the reclamation of arid and semiarid land, [and] for the control of floods” (Miller, 2000). Additionally, the Secretary of the Interior is instructed to operate the dam “in such a way as to produce the greatest practicable amount of power and energy that can be sold at firm power and energy rates” (Miller, 2000). This language that dictates the justifications and operations of Glen Canyon Dam blatantly overlooks the potential costs of the same structure. As no environmental impact studies were mandated or conducted at the time of the authorization for Glen Canyon

Dam, no thought was given to possible impacts of the dam on downstream ecosystems, interested nations or parties, or the Glen Canyon itself.

In 1968 the ignorance related to adverse affects of dams on rivers began to be reversed. The Wild and Scenic Rivers Act of 1968 finally supported the prevention of further dam construction in America on certain rivers by declaring that “outstandingly remarkable [rivers] shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations” (U.S.C. §§ 4331-32). Furthermore, in 1970, the National Environmental Policy Act mandated a comprehensive study of the consequences that any future federal project would incur. Just over a decade after construction on Glen Canyon Dam had begun, concerns for the environment were beginning to replace the manifest-destiny-driven mentality that had ruled the large “dam buildup” of the previous forty years. If an Environmental Impact Statement was to have been prepared in 1957, it is likely that construction on Glen Canyon Dam never would have commenced; however, speculations into the past is not the focus of this paper.

Instead, the above-mentioned congressional acts of the late 1960s, and early 1970s, illustrate a transformation of public opinion that leads to the current debate. The income-generating component of Glen Canyon Dam, the power plant, demands rapid and immense fluctuations in water releases from Lake Powell in order to meet the daily demands of consumers. Although efficient for power generation, these daily fluctuations that were as large as 30,500 cfs (cubic feet per second) began to noticeably affect both ecosystems and recreation in the popular Grand Canyon downstream (Miller, 2000). In a response to a proposed increase in the dam’s power-generating capacity, the Department

of the Interior initiated the Glen Canyon Environmental Studies (GCES), a fifty million dollar examination “to address the concerns of the public and federal and state agencies about possible negative effects of the operations of Glen Canyon Dam on downstream environmental and recreational resources” (Glen Canyon Environmental Studies Final Report, 1988). A sluggish effort to complete the CGES on the part of the Bureau of Reclamation ten years later ultimately led to the Grand Canyon Protection Act (GCPA) of 1992. Aimed at mandating the completion of the original Environmental Impact Statement from the GCES, the GCPA also outlines the management of Glen Canyon Dam “in such manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreational Area were established” (Miller, 2000). As another milestone that brought us one step closer to thoughts of draining Lake Powell, the GCPA marks the first time that pure cash flow and human-driven needs did not dictate the management of Colorado River water, but instead, a Bureau of Reclamation project was managed with environmental benefits as a primary concern.

In *The Place No One Knew*, a Sierra Club book published in 1963, Brower writes, “Glen Canyon died, and I was partly responsible for its needless death” (1963). It is common knowledge that David Brower felt personally responsible for letting Glen Canyon drown in a compromise for Echo Park, but until recently, only the surrendered aesthetic beauty and potential recreational enjoyment of the Glen Canyon were the reasons that Brower and the Sierra Club opposed the dam. The implications of the major acts that now protect rivers and specifically regulate the operations of Glen Canyon Dam reawakened Brower and others in opposition to Lake Powell on much broader grounds.

The now apparent and far-reaching adverse effects of the 186-mile long artificial lake in the desert spurred the creation of the Glen Canyon Institute by Richard Ingebretsen, a group that openly discussed draining Lake Powell and shared this vision with those such as David Brower.

Powerless in comparison to the Sierra Club, the Glen Canyon Institute saw its primary goal propelled to the forefront of the national environmental debate on November 16, 1996. After scarcely a ten-minute speech by Brower, the Sierra Club Board of Directors voted unanimously to endorse the idea of decommissioning Glen Canyon Dam. Ingebretsen's proposition that was now endorsed by Brower and the Sierra Club would leave the dam standing, but re-open the two diversion tunnels already there from the construction of the dam. With a combined ability to allow 200,000 cfs to bypass the dam, these re-commissioned diversion tunnels would certainly be able to handle the Colorado River's highest natural flows (Miller, 2000). Even famed Reclamation head and dam advocate Floyd Dominy agrees that the lake can be drained, logistically speaking. Dominy claims that it would be necessary to cut new diversion tunnels all together rather than attempting to re-open the expertly sealed and reinforced diversions of 1957 (Miller, 2000), but such details are not important here.

Edward Abbey sparked the notion of "decommissioning" the Glen Canyon Dam by means of a single spectacular explosion, and others have proposed slower and less destructive methods of draining Lake Powell. It is, however, the 1996 Sierra Club endorsed plan that is being seriously considered in the arena of politics and public opinion, and therefore that this paper will focus on. Slight variations exist in the proposed execution of such a plan, as seen in the minor technical disagreements by Brower and

Dominy, but nevertheless, the point remains that draining Lake Powell is theoretically feasible, and all parties agree on this. The next step invites debate, as the benefits and costs of draining Lake Powell are analyzed.

If one looks back to the momentum that Brower orchestrated against the dam in Dinosaur National Monument, then the growing support behind the Sierra Club's motion to decommission Glen Canyon Dam will come as no surprise. Perhaps it is merely a sign of the changing times that Bruce Babbitt, Secretary of the Interior from 1993 until 2001, seems to heartily endorse the idea of removing dams. This is an odd outlook to adopt for the head of a department that includes the Bureau of Reclamation as it made a career out of constructing 133 Western water projects for 21.8 billion dollars (Miller, 2000).

Nevertheless, Babbitt has "swung ceremonial sledgehammers to celebrate...the destruction of environmentally-harmful dams" and aspires, "to be the first secretary to tear down a big dam" (Babbitt, 1998).

Currently, the 108-foot tall Elwha Dam and 210-foot tall Glines Canyon Dam (both on the Elwha River in Washington) are scheduled to be dismantled beginning in September of 2011 (NPS.gov). The Condit Dam, standing 125-feet tall in the path of the White Salmon River (also in Washington), will be torn down this fall as well (American Rivers). These three river restoration projects mark the absolute beginning of "large" dam removals. Since 1999, 145 dams have been removed in the United States, yet none have come close in size to the ones about to be removed (NPS.gov). The increasing size of dams in America that are being decommissioned lends promise to those fighting to restore Glen Canyon. Although Glen Canyon Dam is 500-feet taller than the Glines Canyon Dam, the simple fact that some larger dams are seen as no longer necessary and

are being removed is comforting to those who would like to see Lake Powell drained.

Support for the Sierra Club's proposal to decommission Glen Canyon Dam stretches even beyond a former cabinet member's enthusiasm, and in 1997 a Congressional hearing was held to discuss the notion of draining Lake Powell or reducing its water storage capacity. Opponents of the idea hoped to squander the "absurd" proposal immediately, but, "like the 1954 Echo Park hearings and the 1967 Grand Canyon hearings, the 1997 Lake Powell hearings turned out to be a strategic mistake for the dam's defenders" (Miller, 2000), and instead public interest in the revolutionary, and now credible scheme, began to grow. Along the most general of lines, opposition to draining Lake Powell includes the water and power industries, as well as the Navajo Nation and residents of Page, Arizona.

The Bureau of Indian Affairs opposes draining Lake Powell in hopes of defending 38,000 Native Americans in the Upper Basin who depend on Colorado River Storage Project water and power (Martin, 1989). Additionally, the Navajo Nation, the prominent tribe in the Glen Canyon region, aims to capitalize on 50,000 acre-feet of promised Colorado River water rights, a plan that would be complicated without the possibilities of diversions from Lake Powell (Miller, 2000). Otherwise, environmentalists and recreation advocates are found on both sides of the debate.

Power Generation

A steep river that can be trapped in a deep canyon offers an ideal combination to construct a magnificent hydroelectric dam. In addition to other recognized benefits such as flood control and water storage, the clean and reliable hydroelectric power from Glen

Canyon Dam was a major selling point of the dam and the Colorado River Storage Project as a whole. In fact, Brower himself used the lure of extra power-generating capacity to argue for a higher Glen Canyon Dam in the place of a dam at Echo Park (Martin, 1989). In the simplest terms, the higher that stored water can fall from, the more force it can turn a turbine with, and therefore the more clean energy it can generate. Again, it is clear why a tall and narrow dam that backs water into a canyon hundreds of feet deep is ideal for producing hydroelectric power. In the proposed case of draining Lake Powell, then, one of the few costs that can be relatively easily anticipated are those related to power.

The Glen Canyon Dam produces approximately 5000 gigawatt hours of power each year, with a maximum generating capacity of 1,300 megawatts (Harpman, 1999). Without water in Lake Powell, this electricity, and the revenues it generates, simply would be lost. It is important to note that Glen Canyon Dam provides "peaking" or "load-following" power. Because water can be let into, or shut out of, the penstocks and thus the turbines almost instantaneously, hydroelectric dams can easily meet an immediate demand for more electricity. This compares with thermal power plants, which provide "base loads," but cannot respond as quickly or efficiently to "peak" electricity demands (Miller, 2000), as when the need for electricity for air-conditioning surges every summer morning in Phoenix.

The Grand Canyon Protection Act of 1992 already began an unprecedented trend of scaling back hydroelectric output for the benefit of the environment and specifically the Grand Canyon immediately downstream. The completed Environmental Impact Statement within the GCPA limits the daily fluctuations in releases from Glen Canyon to

5,000 cfs in months of lowered Colorado River flows, and 8,000 cfs in months of high flows. In addition, and a most ludicrous notion to traditional hydroelectric dam operators, the GCPA urges occasional releases of up to 40,000 cfs in order to simulate natural floods that restore sandbars and sustain channels (Report to Congress: Operations of Glen Canyon Dam, 2001). These mandates directly stifle power production and cripple the “cash register” aspect of the dam, a preposterous idea to some. Without bold and rapid swings in the water being released from Glen Canyon Dam, the power plant’s load-following ability is notably weakened, not to mention the instances during which natural floods are simulated and precious captured water is allowed to bypass the massive turbines without contributing the slightest amount of electricity or power revenue. Such concessions in the name of the downstream ecosystems have caused an estimated thirty million dollar decrease in annual power revenues (River Resource Management in the Grand Canyon, 1996). No foreseeable events will return the power plant and the Glen Canyon Dam to operations with high and fluctuating releases that only maximize power revenue; under the 1992 GCPA, Glen Canyon power generation must account for Grand Canyon tourism and issues of environmental degradation.

As the power plant within Glen Canyon Dam already operates at a lower pace, relative to its capabilities, then the costs of draining the lake as a whole, a proposition that includes decommissioning the dam and the power plant, are thirty million dollars less. The loss of the remaining power generation as a result of the Sierra Club’s proposal would need to be replaced somehow, and would most likely mean the construction of a thermal power plant in the region. Currently, the Glen Canyon Dam only produces a fraction of the region’s electricity, about three percent, but the dam’s power finds its way

to consumers in Arizona, Nevada, Colorado, New Mexico, Utah, and Wyoming. This consumer base makes up thirty percent of electricity users in the six-state region (Miller, 2000). Without Glen Canyon power, these 1.7 million customers would have access to an existing surplus of power that the Colorado Plateau enjoys; however, the subsidized rates of Glen Canyon power would no longer exist and the price tag for these consumers would increase to market-driven levels (Miller, 2000). Not everyone in the region would suffer, though, as competing utilities with excess electricity would now have a place to sell this power, but at increasingly competitive values due to the decreased supply and new consumer pool. A slightly higher power bill for 1.7 million Southwest consumers may also mean a lower bill for the remaining seventy percent (Harpman, 1999). In most cases the lure of reduced energy expenditures is enough to capture the support of many among this majority; however, Lake Powell's influence in the region goes far beyond power alone.

An often-overlooked method of easing the effects of losing a power source is simple conservation on the part of consumers. The time in which electricity would be needed to replace that lost at Glen Canyon could be greatly extended through the use of conservation. Of course conservation can be performed on a continuum of levels, but the potential to save vast amounts of energy from waste nonetheless exists in rethinking current electricity use habits.

Another adverse effect of decommissioning Glen Canyon Dam would be felt by a power producer of a different kind. The Navajo Generating Station is a 2,250 megawatt coal- fired power plant located just northeast of Page, Arizona. The plant was built in the early 1970s to provide electricity for the Central Arizona Project (CAP), which is a series

of canals, pumping plants, dams, and holding reservoirs that deliver Colorado River water from Lake Havasu to Central Arizona (NGS Water Intake Project, 2005). Aside from producing more electricity than the Glen Canyon Dam power plant and the Hoover Dam Power plant combined (Friends of Lake Powell), the \$350 million Navajo Generating Station was constructed near Lake Powell to ensure it had a dependable supply of cooling water for its three generators. In an agreement that was crucial to the construction of the plant in the first place, the Navajo Generating Station has received its annual quota of 34,100 acre-feet via intakes that pump water directly from the lake (NGS Water Intake Project, 2005). These intake pipes gulp precious water from an elevation of 3,470 feet above sea level, or 230 feet below the lake's full pool level of 3,700 feet. The prevalent dry years since the dam's construction have already threatened the Navajo Generating Station's supply of cooling water, as the surface of Lake Powell in recent years was only 70 feet higher than the minimum level necessary for the NGS water intake pumps to remain operational. However, a complete draining of the lake would render the existing intake pumps utterly useless, for they would be exposed on a cliff nearly 500 feet above the Colorado River below (NGS Water Intake Project, 2005). The costs to remedy this situation would certainly be less than abandoning the power plant as a whole, but electricity demands would be enormous in order to pump the vital cooling water 700 vertical feet from the riverbed (Miller, 2000).

The proposal to decommission Glen Canyon Dam has numerous far-reaching consequences and benefits; yet, the anticipated effects on the region's power generation are the most easily forecasted as little speculation exists surrounding the precise numerical data that is readily available. In this case, the direct monetary losses related to draining Lake Powell would be in the cost of eventually building and operating a power

plant to supplement for the lost hydropower production at Glen Canyon Dam. Currently, a thermal power plant would likely be constructed to ensure a capacity for growth in the Southwest, but it is important to note that the costs of operating a thermal power plant are significantly higher than the hydropower operating costs for Glen Canyon Dam (Miller, 2000). This includes both external and internal costs, as producing hydropower is close to free after a dam is constructed, and air pollution will result if a thermal power plant is to replace the emission-free hydropower of Glen Canyon Dam. In the case of Navajo Generating Station, studies estimate assume air pollution equivalent to 3.5 million automobiles (Lake Powell Water Database). Add these costs to a more complicated and expensive water delivery system for Navajo Generating Station and the drawbacks of draining Lake Powell appear to drastically outweigh the benefits as far as electricity is concerned. Replacing Glen Canyon Dam electricity would certainly invite air pollution and raise energy expenditures for some, while the revenue stream for ecosystem protection and endangered species recovery in the Grand Canyon would cease. It was, after all, revenues from Glen Canyon Dam hydropower that financed the \$50 million Glen Canyon Environmental Studies that culminated in the dam's monitored daily operations and occasional simulated floods (Miller, 2000).

In defense of draining Lake Powell, however, the additional water that would be stored in downstream Lake Mead as a result, would no longer become "wasted" to seepage and evaporation as it sat in the confines of Glen Canyon, but would instead generate an extra \$35 million per year as it passed through the turbines within Hoover Dam (Miller, 2000). Yet, this concession may be too little, and in the arena of power generation, the scales seem tipped against the proposal to drain Lake Powell. Although a

clean energy source would be lost without Glen Canyon Dam backing up the Colorado River, the dynamic nature of this debate becomes evident as other factors are introduced. Sedimentation is a concern that plays into the calculations and predictions in all aspects of Lake Powell; it is the sand in the hourglass that is steadily running out of time. In the case of electricity, sediment accumulation will eventually reach the penstocks that are 465 feet above the submerged riverbed on the upstream side of the dam, and power production will no longer be possible (Harpman, 1999). Estimates as to when this may occur are tricky, but in a few hundred years, hydropower production from Glen Canyon Dam will be obsolete and the dam itself will become obsolete in double that time—an engineered waterfall at the tail of a vast mudflat, all due to the steady buildup of sediment from the muddy Colorado.

Sedimentation

If proponents to drain Lake Powell emanate a sense of urgency, then it is the unyielding deposition of sediment onto the floor of Lake Powell that is driving their haste. The Colorado River is neither the largest nor the longest river in the country, but it is renowned for the amount of suspended earth that it once transported from the Continental Divide to the Sea of Cortez. Prior to the enthusiastic development of the Colorado, 160 million tons of silt was discharged through the Grand Canyon every year, or 11 tons of silt for every acre-foot of water (Martin, 1989). It is not surprising, then, that a reservoir on a river containing 17 times more silt than the Muddy Mississippi is prone to filling in rather quickly. Historically, the mighty Colorado flushed 50-500 million tons of silt out of the watershed every year, but today its reservoirs, and certainly Lake Powell, are shrinking constantly (River and Dam Management, 1987).

In the struggle over draining Lake Powell, the looming reality of what will inevitably happen in the future offers a solid argument benefiting those who align with the Sierra Club on this issue. “Too thick to drink, too thin to plow” (Glen Canyon Institute CEA, 2000) is an old adage that captures the murky nature of Colorado River water; however, the Glen Canyon Dam now traps 85 percent of the sediments that previously rushed through the Grand Canyon, releasing clear and cold, sediment-starved water instead (Myers, 1998). Also, the springtime floods that once transported sediment, built beaches, and restored critical habitat for endangered species no longer enter the Grand Canyon (River and Dam Management, 1987). As a result, the character of the river downstream of the dam has been severely altered while the life expectancy of Lake Powell itself continues to diminish.

The awe-inspiring canyons that confine the Colorado River to its serpentine course throughout the Southwest are the direct result of a steep river that transported an incredible amount of rough sediment to scour cliffs and dunes. In the Grand Canyon, just as in any other stretch of the Colorado, this flowing earth settled in places to provide a base for riparian vegetation and a home for canyon-dwelling creatures. In the more mellow Glen Canyon, such sediment-driven habitat on the banks of the river was much more prevalent as excited flows to wash these beaches away were less common (Myers, 1998). The Grand Canyon, as seen today however, is much different without the constant influx and removal of silt. Sandbars and beaches used by both wildlife and adventure-seekers are no longer replenished by the river’s sediment load. Native fish suffer in the now clear river, and scientists fear the outcome of a continued sediment-free Grand Canyon as well.

Moving our focus upstream and into Lake Powell itself, the sediment problem lies in its excess, rather than its absence. Needless to say, the 710 foot tall Glen Canyon Dam prevents any sediment from continuing downstream. Not only are the penstocks that release most of the lake's water downstream located 465 feet above the dam's base (Miller, 2000), but ground-level release works would still contain minimal levels of sediment as the narrow 186 mile long reservoir allows plenty of time for particles to settle to the lake's bottom before they reach the dam. Still, estimates maintain that the canyons of Lake Powell will completely fill with sediments in 200-800 years (Myers, 1998), varying with future sediment flows. A figure such as this is very difficult to accurately predict, as sediment accumulation is a phenomenon that takes place hundreds of feet under water and at different rates in every location, but the most reasonable predictions envision Lake Powell as nothing more than a vast mudflat behind an arching 710 foot waterfall in as few as 300 years (Miller, 2000). Ten years ago, the storage capacity of Lake Powell had already been reduced by 932,000 acre-feet due solely to sedimentation (Myers, 1998), and at a rate of at least fifty thousand more acre-feet per year accumulating (Miller, 2000), the relatively short remaining lifespan of Glen Canyon Dam is no surprise.

Ignoring the final fate of Lake Powell, sedimentation is still eating away at the National Recreation Area's benefits, just as it eating away at the dam's productive future. In the cases of recreation and storage, the steady increase of silt year after year into the reservoir will translate to diminishing benefits. Other positive aspects of the dam, such as power, will also feel the impact of sedimentation one day in the future instead of slowly along a line of diminishing returns.

Every day in which Glen Canyon Dam stands and operates as is, the longer that it will take to restore Glen Canyon if the reservoir is drained. As Scott Miller writes it in the *Stanford Environmental Law Journal*, “the accumulated sediments themselves and their adverse effects on the downstream environment will be much more difficult to deal with in 150 years than they would be in fifteen” (2000). This is to say that, while the costs to recreation, storage, and eventually power are all increasing constantly as the lake remains, the costs of draining the lake are also on the rise as time drags on. Therefore, the issue of sedimentation is a driving force behind decommissioning the dam. For instance, the Upper Basin states currently use significantly less water than the annual 7.5 million acre-feet allotted to them in the 1922 compact; however, by the time the Upper Basin has developed enough to claim this entire allotment, and the enormous storage capacity of Lake Powell is effectively put to use, tangible benefits of the lake may well be nonexistent due to the accumulation of sediment within the storage sink.

Advocates of the dam draw attention to the unsightly, rancid, and possibly toxic expanse of mud and silt that would be left behind if Lake Powell were to be drained (Friends of Lake Powell). At the same time, the fate of downstream Lake Mead is drawn into question, as it would then have to trap and contain all of the sediment that was previously impeded by Glen Canyon Dam. Lake Mead, being the Lower Basin's main source of storage would experience an exponential increase in sediment inflows and the problem now discussed regarding Lake Powell will become that of Lake Mead as the storage capacity behind Hoover Dam is rapidly reduced along with the reservoir's lifespan (Miller, 2000).

In response to critics who worry about the leftover tons of silt and mud, if the lake

were to be drained, studies prepared for the Glen Canyon Institute demonstrate that accumulated sediments would be washed out of the National Recreation Area in 2-6 years under natural flow estimates (Glen Canyon Institute CEA, 2000). Recently exposed side canyons as a result of low lake levels provide a viewing window in support of these low predictions. Such side canyons along Lake Powell have flushed out the exposed silt in mere months and Dave Wegner of the Glen Canyon Institute contends that in addition to the rapid disappearance of silt left in the canyon, the unsightly white “bathtub ring” will also soon vanish. The bathtub ring marks where the sandstone has been submerged and the long accumulated and characteristic orange “desert rust” on the rock has been bleached and whitened. Such a ring already exists around the lake, and marks the scarcely seen full pool level of the water, yet Wegner’s optimistic claim of a rapid disappearance of this ring, in five to ten years, is based on the fact that an impressive natural reservoir existed in Lake Canyon (a side canyon of Glen Canyon) for years until 1915, and no records of complaints exist that the canyon remained a white-washed mud pit when it was later explored (Miller, 2000). Apparently, the temperamental natural flows within Glen Canyon, combined with the unforgiving desert conditions, are capable of rapidly restoring the inundated gorge to its pre-dam and natural state. That is if the historical case study at Lake Canyon or the recent exposure of Lake Powell side canyons are reliable indications.

Sedimentation is certainly the issue that percolates into every debate over draining Lake Powell. This is no surprise, as it is the constant deposition of this sediment within the Glen Canyon that largely drives the life span of such a project. Yes, an eyesore of possibly toxic silt would be left in Glen Canyon after the waters of Lake Powell escaped

downstream to complete their natural course; however, sources reveal that such a load of mud can be swept away by the Colorado's legendary capacity to carry sediment, and that this would take place much more quickly than many anticipate. In addition, the time scale on which the aesthetic pleasures of Glen Canyon return to pre-dam conditions is vastly different than the timescale of benefits enjoyed by downstream ecosystems. The Grand Canyon, in particular, would again experience large sediment loads that would replenish beaches and riparian habitats. Although a new dynamic between the Grand Canyon's clear waters and young riparian zones has emerged in the absence of seasonal floods and silt, a thought surely must be given to the natural state of things, and such a natural state does not exist in the Grand Canyon today, as much as it may have the appearance of pure wilderness.

Few figures that surround the proposal to drain Lake Powell are concrete and unanimously agreed upon, and the same can be said for the remaining lifespan of Lake Powell before it fully silts in. Yet, it is a fact that the lake will eventually fill in and before that time sediment will undoubtedly reach the penstocks and affect electrical production. These two uncontested truisms surface in every opinion on the matter and will weigh in heavily on the final decision. From a logical point of view, though, the constant diminishing returns and inevitable nature of sedimentation lends enormous support to those in favor of draining Lake Powell. Another monumental issue in this debate however, has its roots in the reason for the construction of the Glen Canyon Dam in the first place. If Lake Powell were to be drained, the effects on water supply, storage, and distribution must be clear, as such matters are political hotbeds in today's arid West.

Water Supply and Distribution

Hydrologic Indicators

The Colorado River, with its elaborate system of diversion and storage works, is currently delivering water to over 24 million people (Status of Federal Western Water Resources, 2001), irrigating 2 million acres of land, generating 4,000 megawatts of hydroelectric power (USBR Annual Operating plan, 2009), and all from a mere 14 inches of average annual precipitation within the boundaries of the basin (Howe, 1990). No river has been asked to do so much with so little water as has the Colorado, resulting in current water demands that are not much less than mean inflows (Status of Federal Western Water Resources, 2001), and likely setting the stage for future water wars. As greenhouse gas emissions continue to rise, fostering a global warming effect, changes in the climate will adversely disrupt Western water resources. Different amounts of precipitation, as well as the intensity, timing and form of that precipitation will pose significant challenges to existing Colorado River water resource infrastructure and distribution.

In addition, changes in snowmelt timing and rates of evapotranspiration will culminate under a booming population in the West to foster water scarcity and resulting conflict. The proposal to drain Lake Powell and the ensuing debate illustrates many water supply concerns that have permeated the thoughts of Westerners. The issues related to water supply, delivery, and losses associated with Lake Powell clearly garner much attention in relation to the proposed decommissioning of Glen Canyon Dam. Major fears evoked from the thought of keeping Lake Powell include the loss of water to bank storage, and the ever-increasing rate of evaporation, as well as projected future droughts that would limit the practical use of the reservoir. Simulations suggest minimal hardships

felt by Lake Powell water users in the event that the dam was decommissioned. Those relying directly on water from the lake, on the other hand, and certain Native American tribes involved would feel direct, and in some cases detrimental effects of a restored Glen Canyon. In addition, proponents of Lake Powell point to a greatly decreased basin-wide storage capacity, and uncertain regulation of flows in the Upper Basin, as reasons to ignore the proposal of the Sierra Club and keep Glen Canyon Dam operating as is.

Clearly, water ends up serving far too many purposes to count or specifically categorize, but according to the United States Bureau of Reclamation, the water of a river basin, and specifically the CRB, can fall into the following beneficial consumptive use categories: irrigation, municipal and industrial purposes, electric power generation, mineral activities, fish and wildlife, livestock, and recreation; all the while keeping in mind associated losses that are incurred within the infrastructure that makes them possible (USBR Annual Operating Plan, 2009). By far the largest portion of water in both the Upper and Lower CRB goes towards agriculture, an activity that sucks up 63 percent of the Upper Basin consumptive use (USBR Report, 2009); while it is still estimated that over a third of the irrigated lands in the same Upper Basin states receive less than a full supply of water, either due to lack of distribution facilities or junior water rights (USGS Comparisons of Average Consumptive Use, 2002). These figures are averages of the consumptive uses and losses from the year 1971 through 1995, and seem to accurately represent CRB water allocation and distribution in the Upper Basin in years since all of the major storage and transport facilities have been in place.

The Colorado River Storage Project is responsible for most of the storage and transport facilities that are found in the Upper Basin, Lake Powell being the key storage

unit. The impetus for the Colorado River Storage Project came following the completion of Hoover Dam and the Lake Mead Reservoir. The compact of 1922 “had given Upper Basin states some security, but when California’s boom resumed after World War II and the city of Phoenix quadrupled in size as well, the Upper Basin states expressed understandable concern that folks in California and Arizona were getting into the habit of using water that was supposed to eventually go to them” (Ward, 2004). Therefore, storage facilities were demanded above the Lee’s Ferry divide, and the 26.2 million acre-feet of Colorado River water that is held in Lake Powell was to serve as a huge savings bank of water that allows development in the Upper Basin states of Wyoming, Colorado, New Mexico, and Utah, and can be drawn upon during dry years to make Colorado River Compact deliveries (Operations of Glen Canyon Dam Report to Congress, 2001).

Although very little Lake Powell water is actually used in the Upper Basin, (no outlet works exist in the lake aside from a diversion to the Navajo Generating Station and another into Page, AZ) the mere presence of a major storage facility within Upper Basin boundaries provides security to those states in the form of regulated flows into the thirsty Lower Basin. Because the 1922 compact generally requires the Upper Basin to deliver seventy-five million acre-feet every ten years, the Upper Basin must assume most ill effects of a drought. However, it appears that the Upper Basin would lose little water throughout the projected future in such a scenario. Currently, the Upper Basin uses only about four million acre-feet of water, or just over one-half of its compact allocation (Miller, 2000). The absence of Lake Powell would most likely affect water use in the Upper Basin only if its water consumption increases drastically. Clearly, the nature of future development and water needs is tricky to estimate and open to much speculation,

but the employment of sophisticated models can help to shed light upon future circumstances, and many such projections exist.

Streamflow indicators and watershed statistics can be used to understand the hydrologic trends of the Colorado River and its tributaries. Records from 1906 to 2000 reveal that the mean annual streamflow over the past century has been 15.1 million acre-feet (MAF) (Christensen, 2006). To look even further into history, tree ring reconstructions, dating to the year 1524, suggest that the long-term average flow may be closer to 13.5 MAF per year (Barnett). These recently understood hydrologic patterns pose a problem for the future of CRB water resources because the inflated historical streamflow from 1906-1990 of 16.6 MAF annually is nearly completely allocated for consumptive use in the Colorado River Compact of 1922 that based its figures on irregularly wet years and used primitive measuring tools to appropriate 16.5 MAF (7.5 MAF to each the Upper and Lower Basin and 1.5 MAF to Mexico after the 1944 Treaty) annually, before accounting for reservoir evaporation (Nash, 1991). The system has only been able to operate reliably in the past due to the Upper Basin currently not utilizing its full entitlement, but instead sufficing on 4.2 MAF of water per year (Status of Federal Western Water Resources, 2001). As drought conditions in the Colorado River Basin appear to be more frequent occurrences, the 60 MAF of total reservoir storage capacity (USBR Annual Operating Plan, 2009) in the basin seems increasingly difficult to reach, let alone sustain.

Lake Mead and Lake Powell, both on the main stem of the Colorado River, are by far the largest reservoirs in the system, with a combined storage capacity of 51.9 MAF, accounting for 86 percent of the basin's total storage (USBR Annual Operating Plan,

2009). On one hand, such massive bodies of water can sustain year-round water deliveries and control peak discharge events, but on the other, a large reservoir surface area in a desert climate that is predicted to experience even warmer temperatures allows for huge amounts of evaporation and therefore unnecessary losses to an already strained watershed; one that is sure to be further taxed in the future.

Most of the reservoirs in the Colorado River Basin are in the Upper Basin, and Lake Powell provides nearly three-quarters of this Basin's active storage (Miller, 2000). Yet, users of Upper CRB water tend to lose about 13 percent of their total annual allocation to reservoir evaporation, an average of 1.7 million acre-feet (MAF). The results from several models agree that the Southwestern U.S. is likely to experience precipitation and evapotranspiration changes that result in less runoff and water availability (Brekke, 2009). As a consequence, the existing water infrastructure may not be able to cope with different patterns of streamflow and still serve their intended purposes.

The fragile equilibrium of such a heavily relied upon river is clearly an important area of study to many, prompting numerous models and simulations that have attempted to predict future streamflows and other changes due to a shifting climate. The most advanced, and therefore presumed to be the most accurate, climate change studies are done by combining downscaled and bias corrected simulated hydraulic and water resource scenarios and models to circumstances driven by observed historical climates that are also projected into the future using simulations to serve as a control model (Christensen, 2004). A general "business-as-usual" scenario is almost always compared

to a control scenario in order to demonstrate what is likely to happen, in terms of climate change, if we continue to emit carbon dioxide at current levels.

Under “business-as-usual” projections, average annual temperatures in the CRB could increase as much as 2.4 degrees Celsius, and, in turn, initiate many other changes (Water in the West, 1998). Average annual precipitation is likely to decrease by up to 6 percent and annual runoff by 17 percent (Christensen, 2006). Most models show reductions in summer precipitation and increases in winter precipitation; however, April 1st snow water equivalent in the CRB is unanimously depicted as declining and by as much as 38 percent (Christensen, 2006). Although such values may be difficult to interpret across the watershed as a whole, all of the above hydrologic changes are reflected, and most easily seen, in reservoir system performance (Christensen 2004). Average total basin reservoir storage always steadily declined in studies; by up to 40 percent over the next 90 years, compared with just 7 percent if carbon dioxide emissions levels were to repeat the trend of the last 90 years (Christensen 2006).

Losses to evaporation and bank storage compound the marginal and diminishing storage capacity of Lake Powell. Although it is difficult to estimate the amount of loss due to evaporation in Lake Powell alone, the values range from about 550,000 to 1,000,000 acre-feet per year, while the lake is at full pool level, asserting that even using the lower estimate, enough water would evaporate in a single Labor Day weekend to be able to satisfy the water needs of 17,000 Western homes for an entire year. Presently, evaporation is the second largest consumptive use of Colorado River water in the entire basin, a staggering amount that ranks only behind irrigated agriculture (Miller, 2000).

In addition to evaporation, water is lost to what is called bank storage, or seepage into the porous Navajo sandstone of Glen Canyon. It is estimated that between 1964 and 1976, as the reservoir filled behind Glen Canyon Dam, 600,000 acre-feet per year was lost to the magnificent orange cliffs, and since reaching capacity, another 350,000 acre feet of Lake Powell water is subsequently absorbed each year (Hansen of Nat'l Parks and Public Lands, 1998). As Lake Powell fills with sediment and the storage capacity decreases, the amount of evaporation will also decrease but at a much slower rate (Miller, 2000). This will happen because the lake is filling in from the bottom up and the surface area of the lake will therefore remain larger in relation to the diminishing total capacity of the canyon to hold water. As a result, the value of Lake Powell as a storage facility, which can be argued was marginal to begin with, will decrease because of the relative increase in evaporation.

It does need to be mentioned, however, that not all of the losses reported above would actually leave the CRB indefinitely, an area of calculation where the disputed figures can be somewhat explained. First, although accounting for a very small amount, some of the water that evaporates is in fact returned to the system in the form of precipitation that falls on the western side of the continental divide. The rest tends to be blown out of the basin entirely and up to the Midwest where it falls as rain (Miller, 2000). Also, if the contents of Glen Canyon were to be drained and largely assumed within Lake Mead, as proposed, the evaporation out of Lake Mead would logically have to increase as well. Experts contend that this new evaporation behind Hoover Dam could be as much as a nine percent, or 70,000 acre-feet, increase due to the greater surface area of Lake Mead (USBR). Finally, one must be careful when reading values for losses to evaporation, as

how each number is arrived at varies slightly. It is usually the case that values predicting lower amounts of evaporation, have already subtracted the assumed evaporation from the Glen Canyon if the lake had never inundated it, thus calculating just the additional losses that are a result of the man-made reservoir. While other, larger estimates, generally demonstrate simply the total losses from Lake Powell to evaporation as occur today. It is even safe to assume that if exposed, much of the water lost to within the Navajo Sandstone of Glen Canyon would also eventually be released back into the system through seeps and springs over many years.

In total, then, draining Lake Powell would likely eliminate the loss of approximately one million acre-feet of water each year (Miller, 2000), a number that can be more easily be agreed upon. Most experts will demonstrate confidence in this final number, as it is much more simple to measure the inflows into Lake Powell and compare them to the regulated outflows from Glen Canyon Dam and combined with the level of the lake's water, a relatively accurate number can be derived that explains the total losses from Lake Powell. The amounts of this one million acre-feet per year, however, that can be attributed to evaporation or bank storage are values much more squabbled over. Another set of projections is the array of computer simulations and models that attempt to reveal future conditions and water resource scenarios, both with and without Lake Powell.

As 70 percent of the Colorado's flow originates as snowmelt, and a staggering 85 percent of streamflow comes from just 15 percent of the basin's area, namely the high country of the Upper Basin, slight temperature changes are greatly amplified when viewed through differences in Colorado River flow (Nash, 1991). Furthermore, despite

the fact that only eight percent of the river's water originates below Lees Ferry, AZ, the CRB is incredibly susceptible to increased evapotranspiration in a warmer climate (Barnett). Generally speaking, increases in temperature within the CRB, and especially the Upper Basin, will increase the rain to snow ratio, shift runoff times, increase evaporation, and decrease streamflow.

One model concludes that reduced reservoir storage due to a drier future climate on average in the West, would greatly affect releases from the Upper Basin to the Lower Basin, potentially sparking conflict. Releases from Glen Canyon Dam to the Lower Basin (as mandated by the Colorado River Compact of 1922) will only be met 59-75 percent of years according to such research (Callaway, 1996). These results show that a relatively modest change in streamflow will result in much larger changes in reservoir storage, a dangerous trend considering that a mere five percent drop in annual runoff is all that is needed for the first Colorado River Compact violations to occur (Christensen, 2006). This model gives no thought to the prospect of draining the lake, but does reveal problems in water deliveries that may be encountered if the current infrastructure, including Glen Canyon Dam, were to be maintained.

Another simulation, on the other hand, demonstrates the effects of draining Lake Powell on water administration, and found that in average years, "decommissioning Glen Canyon Dam would have no impact on water deliveries in the Upper Basin, would decrease the delivery of water to the Lower Basin by one percent (but only cutting into their use of "surpluses," not their Compact allocation), and would increase the total availability of water by approximately 500,000 acre-feet per year" (Miller, 2000). The confidence in simulations such as the ones discussed above thoroughly discredits the

argument of those who would like to keep Lake Powell, yet, in the realm of Western water, politics often trumps actual hydrologic indicators.

Political Concerns

The current rate of evaporation from Lake Powell, the loss to bank storage, and the promise of the proportion of these losses only to increase as time goes on, seems to make the effects of decommissioning Glen Canyon Dam on water availability inconsequential throughout the CRB. Politically, the concept of draining Lake Powell seems insurmountable, as the Glen Canyon Dam is the centerpiece of the Colorado River Storage Project and only major storage reservoir in the Upper Basin. Without the over 26 MAF of storage behind Glen Canyon Dam, over forty percent of all the storage in the basin, or close to the equivalent of two years of the total flow of the Colorado River, would be allowed to flow largely unregulated past Lees Ferry and into the Lower Basin (Miller, 2000). Most importantly, this enormous amount of water now held in Lake Powell is a safety net within the CRB that extends wet cycles in the region well into dry periods to stifle the negative effects of a drought in both the Upper and Lower Basins. The Upper Basin, it is evident, stands to lose the most in the absence of Glen Canyon Dam, but these ill-effects will only be felt in the future when water development and consumption in the Upper Basin increases.

Currently, projections indicate that Upper Basin consumptive water use will swell to merely five million acre-feet by the year 2030, only one million acre-feet more than what is presently used (Miller, 2000), and still 2.5 MAF shy of the Upper Basin's full entitlement as allocated by the 1922 Compact. On top of this apparent under-dog status of the Upper Basin, Lake Powell, the prized storage pool upstream of Lees Ferry, provides

almost no water to consumptive uses in the Upper Basin, but rather regulates deliveries to the Lower Basin (Glen Canyon Institute's CEA, 2000). This is to say that without Lake Powell, water deliveries to the Upper Basin would remain the same as current levels, while rare shortfalls in deliveries to the Lower Basin could be offset through conservation and better management.

As Wayne Solley observes in *Estimates of Water Use in the Western United States*, “the era of building large dams to meet water demand in the United States is drawing to a close...the western United States is in transition from an era of water-supply development to an era of water-demand management and conservation” (1997), and recent statistics on consumption support such a claim. Despite a 35 percent increase in the population of the West since 1975, America as a whole consumes two percent less water than nearly 40 years ago (Miller, 2000). This is not to say that wasteful water practices are still not a problem. The heavily subsidized water of the Colorado River encourages inefficient irrigation practices, so much so that the Bureau of Reclamation believes the Imperial Irrigation District in Southern California to be wasting 200,000 acre-feet every year (Rosekrans, 1997). The issue, however, remains that tailoring growth within the CRB to fit within the limited resources of the river is a much simpler and less problematic approach than harnessing the river to suit our growing needs. Just as in the case of power generation at Glen Canyon Dam, conservation of water by those who eventually put the resource to use can greatly ameliorate stresses of water availability. Draining Lake Powell and eliminating the one million acre-feet of loss seems a step in the direction of water conservation and sustainable management.

The Navajo Generating Station and the town of Page, AZ pump their water

directly from Lake Powell. Surely, the absence of Lake Powell would affect costs of water to each place, but with no other water source around, the Colorado River would still supply the remote power plant and town with the water they need. Page, a town of just over seven thousand residents would not simply vanish without the convenient water from Lake Powell—although decreased tourism would greatly reduce the prominence of Page. All told, political hurdles stand to block the Glen Canyon Dam from being decommissioned on the basis of water availability and deliveries, rather than the lessons from a cost-benefit analysis.

Ways around these political deadlocks have been suggested, such as “changing the Upper Basin's delivery point from Lees Ferry to the foot of Hoover Dam—thereby effectively giving the Upper Basin use of the storage in Lake Mead for delivery purposes” (Miller, 2000); however, revising the Colorado River Compact is another discussion entirely. Evaporative losses and bank storage combined with constant sedimentation eliminates one million acre-feet every year from the lake, while the sluggish water development in the Upper Basin assures uncompromised water deliveries to the Lower Basin for some time in the absence of Lake Powell. Even emergency flood control aspects of Glen Canyon Dam could still be maintained without Lake Powell, if the dam were to be kept in place as is illustrated in the current proposal. The additional nine million acre-feet of storage that would still exist above Hoover Dam, however, would reduce the chances of an emergency flood scenario (Miller, 2000).

Opposition to the Sierra Club's proposal in the arena of water supply, then, lies largely in political agendas. What must be considered though, in either case, is where the extra water, saved from a Glen Canyon Dam that no longer impedes the Colorado River,

would be used. Scot Miller in *Undamming Glen Canyon: Lunacy, Rationality, or Prophecy?* eloquently poses the question, “Would water saved from evaporation be used for satisfying Los Angeles' growing domestic needs, or would it be used to restore the Colorado River Delta? Would Glen Canyon be dedicated to wilderness, off-road vehicles, or curio shops?” (2000). Miller’s quandary captures the ambiguous character of the debate over decommissioning Glen Canyon Dam, but if political barriers could be overcome then draining Lake Powell certainly makes sense in terms of water supply and distribution. Adjusted recreation and tourism within Glen Canyon National Recreation Area and the Grand Canyon below will also occur were Lake Powell not to exist.

Recreation

To many, the most recognizable aspect of the Glen Canyon Dam is the recreational possibilities that are a result. Most people only know that Lake Powell exists because of the boating and tourism offered there, while others downstream put little thought towards the impacts of Glen Canyon Dam on world-class trout fishing and exciting Grand Canyon rafting excursions. The dam’s impacts on these recreational values however, are enormous. Although the Colorado Basin Act lists “recreational needs” as the fourth priority for the operation of Glen Canyon Dam (Glen Canyon Institute’s CEA, 2000), it is a category in this discussion that carries large economic losses and gains, while it is also a major reason that any significant public attention is given to the dam and the lake in the first place.

In terms of direct financial benefits that can be attributed to Glen Canyon Dam, recreation trumps all other associated impacts. According to the National Park Service, tourists visiting Lake Powell contribute more than \$400 million annually to the regional

economy, and another \$21.3 million is generated by the dam-controlled Grand Canyon rafting below Lees Ferry (Miller, 2000). These are concrete and impressive numbers in a region that was largely inaccessible prior to the construction of Glen Canyon Dam. The peak occupation of Glen Canyon before construction of the dam was in 1889, when some 1000 miners lived in the canyon. As the lake filled, however, Glen Canyon saw some 44,000 people eager to take a last look (Miller, 2000). It took the impending demise of Glen Canyon, the actual construction of the dam at the tail of the calm and majestic canyon, to finally lure people into the carved chasms of the Southwest in search of a delight that few before them had experienced. Today, Lake Powell and Glen Canyon National Recreation Area (GCNRA) attracts 2.5 million annual visitors, many finding enjoyment on the 250 square miles of flat-water that is Powell reservoir (Glen Canyon Institute's CEA, 2000). Another 20,000 anglers visit Lees Ferry, 33,000 sightseers ride on motorboats from Glen Canyon Dam to Lees Ferry, and 15,000 to 20,000 whitewater rafters float through the Grand Canyon each year (Glen Canyon Institute's CEA, 2000). In total, swimming, fishing, hiking, boating, water-sports, scuba diving, guided lake tours, scenic air flights, rafting trips down the Colorado River, and other tourist attractions within and below GCNRA generate steady revenue to the communities of the region and open an isolated niche of the country to many more people than would have explored it otherwise. Lake Powell trails in popularity only behind Yosemite National Park (Miller, 2000), and for these reasons, the proposal to drain Powell reservoir encounters yet another wave of dissent.

Not all of these benefits would be lost upon the disappearance of Lake Powell. Certainly, surface recreation on the lake would vanish, as would the trout fishery below

the dam that currently provides \$1.8 million to the region (Glen Canyon Institute's CEA, 2000). The city of Page, Arizona, on the banks of Lake Powell, would suffer from the loss of more than a million people a year who currently pass through on their way to the Lake (Martin, 1989), but rafting in the Grand Canyon would undoubtedly continue, and an untold number of curious visitors would venture into a restored Glen Canyon to raft, hike, and sightsee. If the current popularity of the Grand Canyon is any indication, then the economic value of gained recreation within Glen Canyon would be enormous; certainly tens of millions of dollars. In fact, draining Lake Powell and restoring Glen Canyon would most likely appeal to many more people than the area could accommodate (Miller, 2000).

In 1919 the Grand Canyon became the nation's 17th national park (NPS.gov). With a similar history as the Glen Canyon, the steep and turbid Grand Canyon saw few humans prior to the Glen Canyon Dam. Until 1959 and the start of the dam, a mere 500 people had made the trip through the Grand Canyon. Beginning the very next year, as the fate of Glen Canyon became a certain and grim reality, 200 visitors per year began experiencing the river through the Grand Canyon, a number that jumped to 16,436 by the next decade (Miller, 2000). Now, over 70,000 people annually enjoy a form of recreation within the Grand Canyon, whether it is fishing, rafting, or hiking, and the popular canyon receives 190,000 visitor-days per year, an amount restricted only by the limited number of permits issued to rafters (NPS.gov). In fact, Miller points out that "the direct value of rafting the Grand Canyon alone surpasses the revenues from [Glen Canyon] hydropower" (*Undamming Glen Canyon: Lunacy, Rationality, or Prophecy?*, 2000), a figure that some with a vested interest in Grand Canyon-based businesses fear will decrease if natural

flows were to return through the Canyon, but other figures suggest otherwise.

Rafting in the Grand Canyon will certainly continue regardless of the fate of Glen Canyon Dam, but unregulated flows through the “ditch,” as rafting enthusiasts call it, would alter the commercial structure of the Grand Canyon rafting industry. Uncertainty lies in how much this popular industry stands to change. Many predict a reduced length of the commercial season and increase the unpredictability of whitewater within the Grand Canyon. This would translate to much more dangerous trips in times of high water, and rapids that change erratically from year to year, both serving to increase the danger associated with rafting during a brief season. The rest of the year, on the other hand, would be characterized by variable flows through the canyon, sometimes nearly ceasing all together. The result would be a Grand Canyon Rafting industry with much shorter seasons and instances of increased peril and liability if Glen Canyon Dam were to be decommissioned. Shorter and more unpredictable rafting seasons according to these estimates would cut into the 21.3 million dollar revenues from rafting each year, but when analyzed beyond a financial stance, a heightened sense of danger in a more purely wilderness setting, one that is no longer regulated by a man at a switchboard, is an attraction to adventure-seeking river runners that cannot be economically categorized. The significance of a wilderness experience can constitute the major attraction of rafting to a one-time rafter and seasoned professional alike. In this debate, the unquantifiable joy from a purely wild and exciting river trip may well greatly support the proposal to return the Glen and Grand Canyons to a relatively free-flowing state.

In conflict with the views more commonly read about, an interview with Grand Canyon river guide Morgan Holpuch reveals the possibility of a little affected rafting

industry. As a former guide in Cataract Canyon, a largely free-flowing stretch of the Colorado that runs through Canyonlands National Park and meets Glen Canyon beneath the backwaters of Lake Powell, Holpuch has trouble seeing a drastic change in Grand Canyon recreation if Lake Powell were drained. Holpuch recalls that the unregulated Cataract Canyon commercial rafting season is in fact slightly longer than the current season in the Grand Canyon, even though Cataract Canyon, located far upstream on the main stem of the Colorado, is certain to have less water flowing through it. This is because significant tributaries, including the San Juan River, the Little Colorado River and many other smaller streams join the Colorado River between Cataract Canyon and the lower Grand Canyon, with the possibility of only adding volume to the river.

Again, using the free-flowing nature of Cataract Canyon as a reference, Holpuch compares past low flow scenarios that he has successfully navigated through Cataract (near 1,500 cfs) with the lowest recorded flows through the Grand Canyon. Holpuch remains confident that Grand Canyon rafting will be minimally affected for most of the year, other than spring flooding instances, because the lowest flows through the Grand Canyon are still more than 500 cfs greater than those through Cataract, during which commercial rafting still resumed. Accordingly, Holpuch predicts the engine-toting Grand Canyon rafters to be the only river enthusiasts to be angered by the return of normal flows through the Grand Canyon, as the uniquely timid clientele on their trips may shy away from unpredictable river velocities. This may result in a shift toward more able and enthusiastic patrons within the Grand Canyon (characteristics that most guides appreciate), while warmer water temperatures in a post Lake Powell Grand Canyon may attract the extra business needed to offset that lost on motor-rigs. Either way, the

recreational aspects associated with draining Lake Powell are still secondary to ecology and aesthetics in the eyes of Grand Canyon river guide Holpuch.

Without Glen Canyon Dam, the clear and cold water that escapes Lake Powell and journeys downstream would be replaced by the naturally muddy and thermally variable waters of the past. Trout fisheries that have flourished in the cool, sediment-free water within and just below Lake Powell would suffer greatly upon the return of natural flows, likely eliminating the \$1.8 million trout fishing industry at the base of the dam (Miller, 2000). Yet, some of these losses would be offset if native fish populations were restored. For instance, in the five years after 1963, twelve million trout and five million bass were dumped into Lake Powell, all species that require water temperatures and sediment loads very different from those in the naturally flowing Colorado River (Rogers, 2006). The populations of these fish and associated fishing industries would be negatively affected by draining Lake Powell, but a strong argument exists in the fact that these fish are invasive species that often out-compete the sensitive native species within the Colorado River, and therefore should not be in the water shed in the first place. These monetary losses would almost certainly be reduced as some of the displaced boaters and anglers resumed their watery outings on other Western reservoirs. An often overlooked cost of such popular tourist destinations as Lake Powell, however, is the accompanying pollution and ecological disturbances and these associated harms.

A large portion of the activities enjoyed within GCNRA is limited to affluent visitors (Glen Canyon Institute's CEA, 2000). Owning, renting, and using boats and watercraft is inherently expensive, one estimate assumes the value of boats alone on Lake Powell to be \$191 million (Miller, 2000). Not only does this segregate those who

typically visit Lake Powell based on income, but the emissions from the 1.5 million boaters annually on Powell reservoir add up to a staggering amount of fuel being added to the lake (Miller, 2000). Although 58 percent of visitors participate in off-water, off-beach activities, such as hiking, these activities are almost always accessed by boat or other means that require fuel combustion. All told, about one million gallons of hydrocarbon pollution is dispersed into Lake Powell each year. Two percent of this is, or 20,000 gallons, is raw oil (Glen Canyon Institute's CEA, 2000). This is the equivalent of an Exxon Valdez oil spill into Lake Powell roughly every 15 years. As the most heavily visited of all the areas in the interior West managed by the National Park Service (Martin, 1989), Lake Powell is the recipient of enormous amounts of pollution, an issue that will always accompany popular recreation, but concerns many who imagine what the Glen Canyon may look like without the lake smothering it. The fear of toxic sediments that have accumulated on the bottom of Lake Powell becoming an eyesore and health hazard once exposed is a legitimate one, and the lake only continues to become more polluted due to heavy recreation.

As the National Park Service reported in 1946, the recreational resources within the Colorado River Basin had a unique character that translated to a high recreational potential in its wild, unspoiled canyons (Martin, 1989). This prediction has come true, in part due to the creation of Lake Powell that spans four rural counties that are highly dependant on the related tourist dollars (Glen Canyon Institute's CEA, 2000), but also simply due to the region's distinctive wilderness characteristics. There is no doubt that lucrative recreation will continue in the Glen and Grand Canyons even without Lake Powell, and the diminished pollution that will no longer be deposited into the Colorado

River Basin through Lake Powell is just one convincing point for decommissioning the Glen Canyon Dam, among other positive aspects associated with recreation after a drained Lake Powell. A more speculative and encompassing characteristic of the Glen Canyon Dam, however, is the region's ecology and how this relates to the presence of the reservoir.

Ecology

In the early 1980s, those familiar with the resources and the ecosystem below the Glen Canyon Dam, including Grand Canyon recreation enthusiasts and environmental advocates, began to voice concerns that ecological changes were taking place due to the dam's presence and management. In response to a proposal to increase the generating capacity and peaking power of Glen Canyon's powerplant, the \$50 million Glen Canyon Environmental Studies were begun that ultimately led to the 1992 Grand Canyon Protection Act which recognizes and seeks to diminish downstream environmental impacts of the dam and its management. Grand Canyon rafters had begun to notice the disappearance of sandbars and beaches after the dam trapped the sediment that historically replenished such habitats and rafting necessities. Others too noticed the declining health and prevalence of native fish species within the now cold and clear Colorado River downstream of Lake Powell. The health of canyon ecosystems, whether it was raised for underlying recreational benefits or simply due to a newfound environmental concern, was, for the first time publicly popular. So much so, that legislation was passed specifically to address the negative impacts on the vegetation and wildlife in the Grand Canyon from the operations of Glen Canyon Dam above. Clearly

the environmental sentiment that was utterly absent during the construction of Glen Canyon Dam was beginning to take priority in the later part of the twentieth century.

Today, the same concern that prompted the 1992 Glen Canyon Protection Act is much more widespread and legitimate. Although scarce data exists that allows researchers to comprehensively describe the character of the Glen Canyon river system before the closure of the Dam (River and Dam Management, 1987), far reaching effects of the dam, the reservoir, and their collective operations have since been identified and studied in an attempt to fully understand the changes that have resulted from the construction of Glen Canyon Dam. Richard Ingebretsen of the Glen Canyon Institute remains certain that, “we would not be allowed to build Glen Canyon Dam today” (Ward, 2004), rather than during the late 1950s when no NEPA existed to require a scientific assessment of the environmental impacts of building dams. In order to predict what changes have occurred in the Colorado River Basin since the filling of Lake Powell, and attempt to envision what a restored Glen Canyon and Grand Canyon may look like, it is necessary to review the ecology of the ecosystem before the dam.

The terrestrial and aquatic ecosystems of the immediately affected canyons were only briefly studied prior to Glen Canyon Dam. The consequence of this lack in scientific data is a less influential representation of what the river system would look like after the draining of Lake Powell because many anticipated changes are inherently speculative. In addition, the Colorado River’s ecosystem prior to the dam was already altered. Invasive fish species, several that are direct competitors or predators of the native fish, arrived in the Colorado River as early as the late 1800s (Carothers and House, 2000). Perhaps ecosystems within the Colorado River were in peril long before the conception of any

dam in Glen Canyon. Finally, scientists contend that the fragile and dynamic Grand Canyon below the dam has yet to reach a state of ecological equilibrium since the dam first altered its natural flow nearly a half century ago (Carothers and House, 2000). This also contributes to the difficulty involved with determining the influence of reservoir drainage on biological systems both above and below Glen Canyon Dam. Nevertheless, the ecological impacts are crucial in the debate that will decide the fate of Lake Powell.

The undeveloped and unregulated Colorado River in the Glen and Grand Canyons was a moody and seasonal waterway. Flows were characterized by being highly variable with heavy sediment loads and water temperatures that could pendulum by as much as 50 degrees Fahrenheit (F) between winter and summer (Carothers and House, 2000). After the dam, however, water released (200-230 feet below the surface of the lake) was clear and cold without the spring floods that historically built beaches and restored habitat (Report to Congress: Operations of Glen Canyon Dam, 2001). Above the dam, a lake took the place of Glen Canyon and trapped the huge sediment loads. Below the dam, seasonal flows were eradicated and by the early 1970s temperatures of water discharged from the dam averaged 48 degrees F and never varied more than 4 degrees F between the seasons (Carothers and House, 2000). The result was a new ecosystem in both canyons, different from those of the pre-dam history.

Pre-Dam Ecology

I will begin at the bottom of the food chain to characterize the differences between the Colorado River before and after Lake Powell. Although never exactly measured in the Glen or Grand Canyon prior to the dam, primary productivity within the river was surely limited. This was a result of the constantly shifting and never stable river

bottom that was made up of steadily flowing fine sediments. Also, the mud-colored water blocked nearly all solar radiation into the water, limiting algae growth and in turn, the proliferation of macroinvertebrates and aquatic insects (Carothers and House, 2000). Therefore, the food upon which the native fish species in the Colorado River survived was relatively scarce and largely came from outside of the aquatic ecosystem, such as terrestrial insects (River and Dam Management, 1987). Above primary productivity, the native fish within the Colorado River were rare and were extremely well adapted to the unique river they called home.

The extreme variations in water flow, temperatures, and sediment load through the Glen and Grand Canyons that supported few aquatic insects or algae created a very harsh ecosystem that demanded specialized residents. Adapted fauna is just what evolved. Only two families and six genera of fishes are native to the Colorado River (Carothers and House, 2000). Six species are endemic (found nowhere else) to the Glen and Grand Canyon region. These fish within the swift and muddy Colorado are “remarkably large, muscular, and streamlined-with small, depressed skulls, and large, muscular keels on their backs providing them with the power and hydrodynamics to navigate the fastest major river in the United States” (Miller, 2000). Very small eyes and thick skin, nearly devoid of scales, reduces friction and allows these fish to weather sediment abrasion. Finally, these endemic species evolved long life spans to account for the unpredictable environment in which they live (Miller, 2000). In such conditions it is no surprise that only eight species of fishes lived in the canyons of the Colorado River at all, but such specialized creatures have proven to react poorly to complete regulation of flows and temperatures, while being less than ideal competitors as well.

The natural Glen Canyon differed from the Grand Canyon downstream in many ways. Glen Canyon offered a less constricted river channel and lost much less elevation than the Grand Canyon, just two feet every mile through the Glen compared to eight feet per mile in Grand Canyon (Carothers and House, 2000). Needless to say, the river through Glen Canyon rarely constituted a rapid, while the turbulent nature of the Grand Canyon is still legendary. Soft Navajo Sandstone that was constantly eroding abutted this wider and gentler channel through Glen Canyon. The result was multilevel river terraces and a healthy array of sandbars that all supported a rich riparian habitat compared to that in the Grand Canyon (Carothers and House, 2000). Native plant species such as sandbar willow, baccharis, and arrowweed thrived alongside larger hackberrys, Gambel oaks, and Fremont cottonwoods. Non-native tamarisk was also present prior to the Glen Canyon Dam (Carothers and House, 2000). This vegetation constituted a dense row of shrubs and trees that lined Glen Canyon riverbanks, only to be destabilized by the moderate spring floods. Above the flood line and on terraces, more drought-tolerant, long-rooted shrubs were common. Within these various vegetation havens, as many as 197 animal species were likely to have existed according to expert estimates. The Glen Canyon Environmental Studies documented 96 species in the short time that scientists observed the area, and more were surely overlooked. Small mammals made up a fraction of the animal life, including beavers, as did birds, reptiles and amphibians (Carothers and House, 2000).

Prior to 1963 the Grand Canyon, on the other hand, resembled a much more desolate ecosystem. The combination of a narrow channel and steep gradient confined by less erosive cliffs, led to a different vegetative landscape than that seen in Glen Canyon.

Due to the steep and constricted nature of the Grand Canyon, spring floods aggressively climbed the banks, as high as thirty feet at times, and annually scoured any vegetation that attempted to take hold along the river's edge (Carothers and House, 2000). The result was a "scour zone" where only grasses and low growing herbaceous vegetation lined the river for most of the year. The absence of permanent trees along the river banks likely could not have supported much of a bird population, and again, small mammals, reptiles, and amphibians existed, but in much smaller numbers than in Glen Canyon. Above the 100,000 cfs waterline in the Grand Canyon a permanent band of vegetation consisted of acacia, mesquite, redbud, hackberry, and Apache plume, with desert scrub even higher (Carothers and House, 2000). This is no longer the case ever since the gates of Glen Canyon Dam were closed.

Post-Dam Ecology

Obviously Lake Powell inundated the Glen Canyon and the two ecosystems are incomparably different. The vegetation and animals in Glen Canyon did not survive, but a new environment was created, and new species were allowed to flourish. Fish within Lake Powell are almost entirely non-native, although rarely is a native fish spotted in the extreme upper ends of the reservoir. Invasive fish species were put into the reservoir immediately following the dam's completion in order to assure a healthy sport fishery. This stocking of non-native species continued until 1992 and in the five years after 1963, twelve million trout and five million bass were dumped into Lake Powell (Rogers, 2006). Now, over ten alien fish species account for most of the animal life in the lake, the most common being threadfin shad, smallmouth bass, striped bass, bluegill, green sunfish, channel catfish, carp, and walleye. The Bureau of Reclamation has used hydroacoustic

techniques to estimate the actual numbers and types of fishes in Lake Powell, and assumes that as many as one-half-billion non-native fishes live within Lake Powell (USBR Final Environmental Impact Statement, 2000). Where possible, vegetation is dominated by tamarisk and Russian thistle, two inhospitable and exotic species. Terrestrial animals are also scarce along the barren rock or desert shore of Lake Powell, but waterfowl have prospered and as a result, so too have their predator peregrine falcons. Bald eagles, almost never seen in the natural canyons, have increased in abundance since the arrival of Lake Powell and its plentiful fish population (Carothers and House, 2000). Downstream of the dam, however, the altered ecosystem that has resulted can be directly compared to what existed before the dam.

Glen Canyon Dam eliminates the normal high-peaking hydrograph that sculpted the harsh habitats of the Grand Canyon. As the reservoir filled over seventeen years, the flow through the Grand Canyon only exceeded 31,500 cfs on a few rare occasions, and the former yearly flows in excess of 90,000 cfs were not experienced again until the mismanaged floods of 1983 (Carothers and House, 2000). Under a regulated hydrograph, spring floods ceased scouring the banks of the Grand Canyon and permanent riparian plants, similar to those that previously lined the shores in Glen Canyon, took hold (Carothers and House, 2000). These species crowd the diminishing sandbars, as riparian real estate is limited in the steeper and more confined canyon. The new growth does provide for many more animals than previously existed in the Canyon, and “at least twenty-five species of birds have either expanded their range into the new habitat or increased in abundance” (Carothers and House, 2000). A new wealth of insects from the arrival of recent foliage has combined with a significant increase in primary productivity

within the river to vastly expand the food resources available to fish. This new in-stream algae is the result of now clear water that allows for greater light penetration and supports dozens of species of invertebrates (Carothers and House, 2000). Such drastic increases in food availability has impacted the density of fish within the Grand Canyon, while the now stable flows and cold water has affected the type of fish.

The purely native fish within the Colorado River include humpback chub, rundtail chub, specked dace, flannelmouth sucker, razorback sucker, bluehead sucker, Colorado pikeminnow, and bonytail. These fish had evolved to live in the variable Colorado River and had done so for millennia; however, warm-water non-native species arrived long before the Glen Canyon Dam and began to compete with the native populations. As Miller solemnly recalls, “historically, there were only eight species of fishes native to the Colorado River in Glen and Grand Canyons. Today five of the eight native species are endangered or have been extirpated, and of these five, only one species exists as a naturally reproducing species” (Miller, 2000). The endangered Colorado pikeminnow was wiped out likely because of the coldwater discharges and interruptions to their migratory behavior due to the dam. Also, the endangered razorback sucker, is assumed gone from Grand Canyon yet hardly persists downstream in Lake Mead (Carothers and House, 2000).

Alien trout were purposefully introduced into the coldwater tributaries of Grand Canyon with the creation of Grand Canyon National Park in 1919, and non-native sport fish were aggressively stocked in Lake Mead after the completion of Hoover Dam in 1935. Some of these fish inevitably ended up in the Glen and Grand Canyons. In fact, by the time Glen Canyon Dam was finished, fourteen species of non-native fish had already

been reported in a system that once held only eight native species (Carothers and House, 2000), and twenty types of exotic fish now exist in the Colorado River (Miller, 2000). Glen Canyon Dam directly affected the native fish populations in the Grand Canyon. From the time when river temperatures stabilized near 48 degrees F in the 1970s, both native and non-native warm-water fish have suffered an overall decline, while coldwater species, namely rainbow and brown trout, have increased in numbers. The Grand Canyon's native species have difficulty spawning in the cold water that is released from Glen Canyon Dam. As a result, and due to competition from invasive fishes, struggling native fishes are largely limited to the Colorado River tributaries that still experience natural water temperatures and hydrographs (Miller, 2000). Such Colorado River tributaries have since become a refuge for the lingering native species. The Little Colorado River that joins the Grand Canyon about 75 miles below Glen Canyon Dam, supports the largest remaining population of endangered humpback chub, around 75,000 mature fish (Carothers and House, 2000). Overall, the increasingly populous and regulated Colorado River below Glen Canyon Dam lends a competitive advantage to exotic fish species rather than the native fish species that are tailored to extreme variations in environmental conditions and thus little competition. Finally, the dam's impacts can also be seen as the natural spawning migrations of many of the native fishes is blocked by the 710 foot-tall concrete structure of Glen canyon Dam that subsequently destroyed nearly 200 miles of native fishes' prime habitat in Glen Canyon (Miller, 2000). With the knowledge of how the ecology within the Glen and Grand Canyons changed after the dam, possible effects of draining Lake Powell can be inferred.

Ecology After Decommissioning Glen Canyon Dam

The Glen Canyon Institute has suggested that the reservoir reasonably could be drained in ten to fifteen years. Over this time frame drastic ecosystem changes would be minimized, but still enormous. It must also be kept in mind that any action performed today must comply with the Endangered Species Act (ESA), Clean Water Act, National Environmental Policy Act, Law of the River, and other pertinent laws unless Congress legislated otherwise, which is a complicated proposition (Carothers and House, 2000). This means that environmental effects of the lake's drawdown would have to be taken into account when designing a release scheme. Most likely to be affected by the decommissioning of Glen Canyon Dam will be listed species that are either endangered or threatened according to the ESA, a broad and powerful piece of legislation that can prohibit such an undertaking if certain species were likely to be harmed.

In this case, the endangered humpback chub is the species in question, as draining Lake Powell is believed by some experts to be "the death knell for the most significant remaining recruiting population of humpback chub in existence" (Carothers and House, 2000). A careful drawdown of Lake Powell would certainly be a priority, but some factors are simply out of our hands. Until 230 feet below the top of the dam the reservoir could be emptied through the penstocks, and then through the river outlet works that are another 16 feet lower on the dam. Releasing any water below the level of the outlet works would require either re-opening the two 41-foot-diameter diversion tunnels that were used during dam construction or excavating new ones (Carothers and House, 2000). The result of this stage-based draining regime would be abruptly changing temperatures at various points of the drawdown. Initially, releases would remain cold, but would warm as

the reservoir level dropped and water was drawn from nearer the surface. The location of withdrawal would inevitably have to shift to the bottom of the reservoir at some point and release temperatures would abruptly decrease, only to gradually warm again (Carothers and House, 2000). These dramatic temperature shifts would certainly stress the Grand Canyon species, but another concern during the later stages of draining Lake Powell would be poor water quality.

From nearly absent currents, especially at great depths, Lake Powell is chemically stratified, with a large body of saline water accumulating on the bottom. This region of high salinity stagnates over time, becoming increasingly anaerobic as levels of dissolved oxygen decrease. Eventually the only life forms that can survive at depth are anaerobic bacteria that produce such toxic products as hydrogen sulfide and ammonia (Carothers and House, 2000). If the ecosystem within the Grand Canyon prevailed through temperature swings and dangerously low oxygen levels during drawdown, then the unfathomable number of non-native fishes from Lake Powell that would be swept into the Grand Canyon may be the final and most testing risk of decommissioning Glen Canyon Dam. Steven Carothers and Dorthy House estimate that “during certain stages of reservoir depletion, upwards of 250,000 non-native fishes could enter Grand Canyon from the reservoir each week” fearing “such an onslaught would overwhelm downstream habitats and organisms, including humpback chub and the resources essential for its survival” (2000). Not only would this harm to the humpback chub violate the ESA, but the most significant remaining population of humpback chub in existence is found in the Grand Canyon and the species as a whole may face certain extinction without the Grand Canyon faction (Carothers and House, 2000). Primary and secondary productivity and

fish populations eventually would stabilize at low levels as the lake species died out, but this may come at the cost of the humpback chub. Other native species that were likely wiped out in the Grand Canyon during the drawdown period would have to reestablish a population in the main river channel from tributary niches and vigorously compete with non-native residents.

In addition, a return to highly variable temperatures and inflated sediment loads from lake deposits would be feared to result in a collapse of the aquatic food chain. What few well-adapted native fish remained may enjoy an advantage in such circumstances, but other warm-water invasive fishes would also survive and occupy habitat that would otherwise belong to the native species (Carothers and House, 2000). Extremely swift flows through the diversion tunnels around the dam may still inhibit fish from upstream passage as well, just as the dam once did. Bald eagles and peregrine falcons would decrease in numbers when the river returned to natural, as swallows, swifts and rainbow trout would largely vanish; yet both of these iconic birds have experienced a healthy rebound from near extinction and neither species would be affected as a whole. Other ecological effects of draining Lake Powell would be far-reaching and difficult to foresee. For instance, habitats and species associated with seeps and springs would thrive as the massive quantities of water stored in Glen Canyon's sandstone walls flowed to the surface (Johnson).

Endangered and native species tend to assume a central role in debates that propose an ecologically sensitive action, and the unique species that are found only in the Colorado River Basin are no exception. Counter-intuitively to many, draining Lake Powell may well accelerate the loss of native species; just as it is hard to believe, but

possible that creating the dam in the first place could have prevented non-native warm-water fishes from gaining the upper hand in the main stem of the river. Therefore, the dam may have helped the already troubled native fish endure an invasion from exotic warm-water species even as it degraded their habitat. The three other Colorado River fishes protected with endangered status, razorback sucker, Colorado pikeminnow, and bonytail, on the other hand, would likely not be directly affected by draining the reservoir. All three species have disappeared from the Grand Canyon and probably never were common there anyway (Carothers and House, 2000).

If Glen Canyon Dam was initially condemned because it destroyed the wonders within a pristine wilderness, opposition to the dam now cite the far-reaching ecological consequences as major reasons for the call to restore Glen Canyon. Former Secretary of the Interior Bruce Babbitt recalls, “I was up here when this dam was built in the '50s, and at the time it didn't occur to anybody the relation between the dam and what would happen downstream” (Miller, 2000), in a statement that captures the central problem of the Glen Canyon Dam. It is commonly accepted that a natural ecosystem is a sustainable one, and therefore protecting or restoring a river’s natural hydrograph, where seasonal low and high discharges return to historical cycles is necessary; but in this specific instance, humans may need to further intervene on the behalf of select and troubled species. Draining Lake Powell would restore much of the Colorado River to a more natural condition, but this is likely at the cost of native and endangered species. So far in this discussion, I have assumed minimal human intervention in cleanup or restoration after the decommissioning of the dam; however, harboring and then re-introducing species such as the humpback chub after the most drastic ecological changes of the

drawdown have subsided may be the answer to preserving the species as a whole. Under such a scenario, during which care should be taken to ensure the survival of all native species in the Colorado River, draining Lake Powell again looks desirable.

Conclusion

One trend among humankind is clear: we have an insatiable appetite for conquering the natural world, and this often leads to unintended consequences. There is no doubt that the Bureau of Reclamation, in a Herculean effort, brought much of the West's water resources under control, at least for the time being. Yet, as has happened countless times before from various endeavors, the unanticipated downfalls of these large dams that stall nature's onslaught are just beginning to be contemplated and understood. In the case of Glen Canyon Dam, the real cost is not only 272 million 1963 dollars, maintenance costs of \$11-29 million per year, and 1.2 million acres of drowned America (Sibley, 2000). Other intrinsic values are often overlooked. The purpose of an objective evaluation such as the one that I have conducted is to uncover these convoluted consequences and separate them from the often-intertwined mess of benefits and uncertainties alike. Some of the seemingly cut-and-dry economic costs and benefits of Glen Canyon Dam are currently so murky, that perhaps billions of dollars can be sincerely incorporated into both arguments, not to mention an endless stream of related impacts that would greatly influence support for or against draining Lake Powell. Clearly, before we hastily tear down or decommission dams such as the one in Glen Canyon, many debates like the discussion outlined above must be settled. Still, we won't be ensured safe haven from another host of unforeseen effects. Glen Canyon Dam is unique in the fact that it is the first, and still one of the only, dams of its stature that may actually

be decommissioned, but the nature of being a pioneer implies that much more is left to speculation. Throughout this paper I have divided the anticipated effects of draining Lake Powell along the cleanest lines that I could find, yet the complex interdependencies of such a question are still evident.

Decommissioning Glen Canyon Dam would be harmful to society through consequences such as the loss of clean, load-following hydroelectric power and the resulting need for a polluting thermal plant. Revenues from related tourism and power would be lost or shifted, and one misstep during the drawdown could result in devastation to multiple, already fatigued, native fish species. Political tempers would flare if the only major storage facility in the frequently neglected Upper Basin were drained, and Glen Canyon would take decades or more to be restored. This seemingly daunting list, however, is overshadowed by the benefits that would be enjoyed, directly and indirectly through a restored Glen Canyon based on my research and comparisons.

Simply the feasibility of draining Lake Powell immediately makes Glen Canyon Dam a candidate for scrutiny. Thus, after answering the question of how, more time can be devoted to studying why Lake Powell should be drained. Here is where the debate splits, and for one simple reason: the lack of comprehensive and primary studies of the possible effects of decommissioning Glen Canyon Dam in the detail necessary to settle the central question of this paper. Such studies are costly, and no money has ever been made available to carry out the research. In fact, just the opposite is the case, as concerned members of Congress inserted a rider to the 1999 and 2000 appropriations bills to slow the momentum of the Sierra Club's proposal. The latter rider explicitly blocked the prospect of money being "used to study or implement any plan to drain Lake

Powell or to reduce the water level of the lake” (Miller, 2000). Cursory speculations and models can be compiled to form an enlightened opinion on the matter, but until the costs and benefits of decommissioning Glen Canyon Dam are thoroughly and explicitly analyzed for that very same purpose, predictions will run amuck into every facet of possibilities. Former Secretary of the Interior Bruce Babbitt encompasses the modern environmentalist’s view of large dams, challenging “dam owners everywhere—including the U.S. Bureau of Reclamation, the Army Corps of Engineers and other federal agencies—to defend themselves, to demonstrate by hard facts, not sentiment and myth, that continued operation of a dam is in the public interest.” And acknowledging that “This is especially true of Glen Canyon Dam, a dam built on assumptions of necessity and with a blind eye to the environment and our changing values” (Babbitt, 1998). Babbitt’s criticism of Glen Canyon Dam illustrates the impetus for the desire to drain Lake Powell. The Colorado River Storage Project Act was devised at a time during which an utter absence in the understanding of the dam and its effects on the downstream environment had been made evident. It is the shifting of views though, away from the narrow-minded conquests of the big-dam era, and towards ecological, and even biosphere-wide, notions of sustainability that brings the current and future benefits of Glen Canyon Dam into question.

For the above reason, I considered the Sierra Club’s proposal and, from the current data available, concluded that decommissioning the Glen Canyon Dam is best. In hopes of avoiding complication I analyzed the costs and benefits of draining Lake Powell assuming minimal human intervention beyond the act of bypassing the dam. It is naive to believe however, that humans will not contribute to the restoration of the affected

ecosystems. Therefore, a condition must be met in order for the draining of Lake Powell to remain on the “to do” list in my opinion. Power generation from the dam is already reduced due to environmental concern; sediment will eventually fill in Lake Powell; the reservoir’s intended purpose as a storage facility for the upper basin will not be utilized for years to come; and recreation in the desert Southwest will continue after the disappearance of Lake Powell. For these, and other reasons outlined in the paper, draining Lake Powell makes sense. The notion of inflicting certain harm on few native species downstream concerns me, yet a remedy may lie in a concerted effort to reintroduce the humpback chub to the Grand Canyon well after the drawdown of the reservoir and the associated dangers have mostly passed. Other services are certain to be aided by conservation ecologists, yet the prevention of species extinction is important in a successful and supported proposal to decommission Glen Canyon Dam. Given enough time, aquatic and terrestrial habitats above and below the dam would be expected to resemble pre-dam conditions, or at least develop a new natural sustainability, but the fact remains that the original goals of the dam are no longer consistent with the recently recognized environmental consequences of all large dams. For this reason, the Glen Canyon Dam has become the subject of debate in many other cost-benefit analyses’, the results of which should seal the fate of Lake Powell by decommissioning Glen Canyon Dam.

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